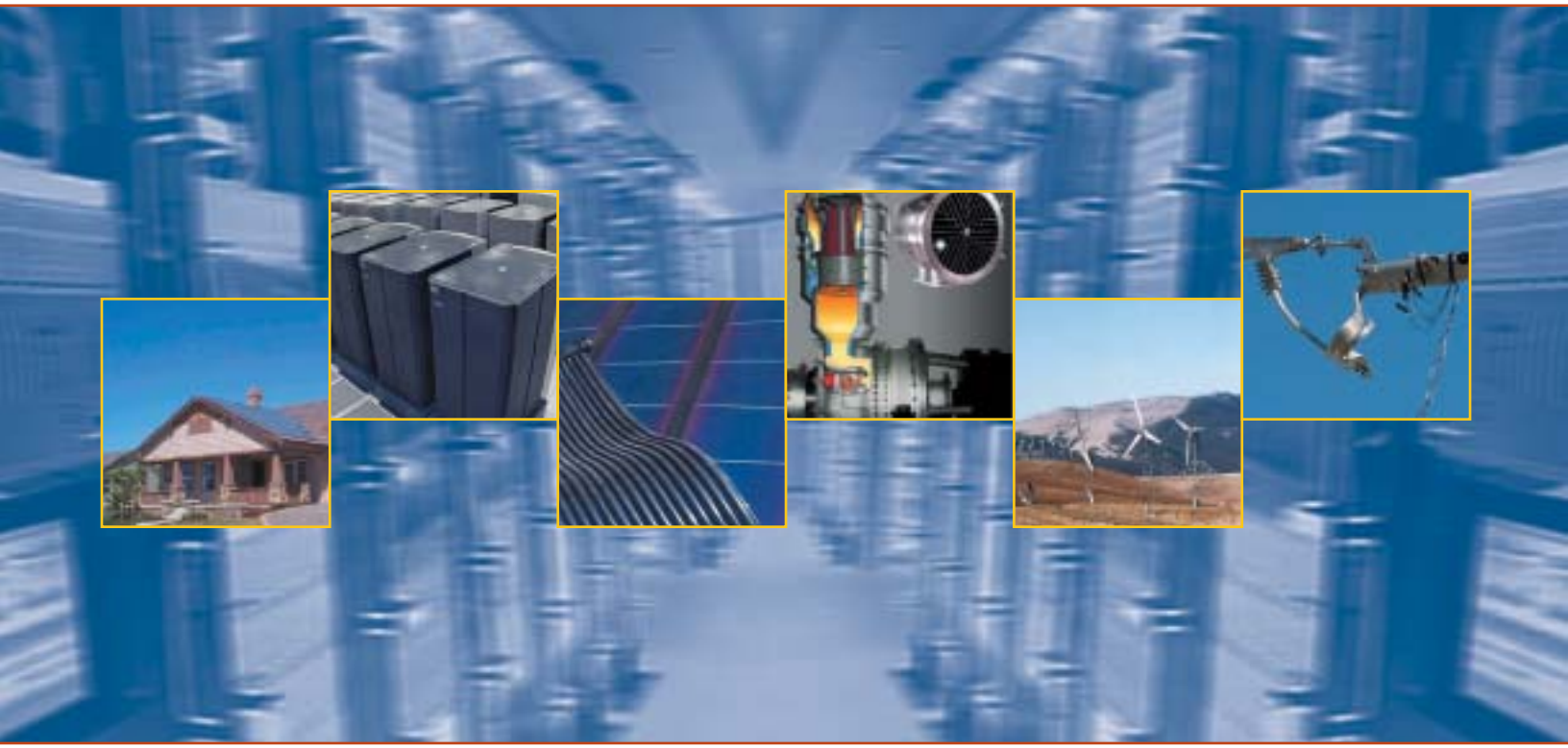
Public Interest Energy Research

ANNUAL REPORT 2002



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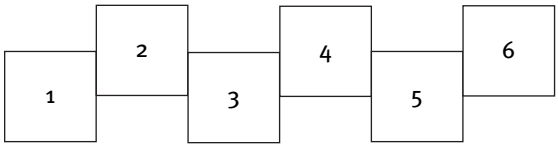

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6. Energy Systems Integration
Material Integrity Solutions' sagging line mitigator (SLiM) prototype

Public Interest Energy Research

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EXECUTIVE SUMMARY

PIER Program Background

Following the deregulation of California's electric services industry in 1996, the Legislature authorized the California Energy Commission to conduct public interest energy research, development, and demonstration. In accordance with the Public Resources Code (PRC) Section 25620.8, the Energy Commission has developed its fifth annual report to the Legislature concerning the Public Interest Energy Research (PIER) program, for the period January 1 through December 31, 2002. Legislation across the nation continues to show that California's PIER program serves as a model for many other states. The Energy Commission has also enhanced its funding through a number of effective collaborations with the U.S. Department of Energy (DOE), increasing the program's benefits to California.

Current Status of the PIER Program

The PIER program is organized into six program areas:

- Residential and Commercial Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water (IAW) End-Use Energy Efficiency
- Renewable Energy Technologies
- Environmentally-Preferred Advanced Generation (EPAG)
- Energy-Related Environmental Research
- Energy Systems Integration (ESI), including transmission, distribution, and enabling technologies

In addition, the PIER program conducts the Energy Innovations Small Grant program that funds early feasibility research in new technology concepts in advance of the six PIER program areas.

During 2002, the Energy Commission approved PIER awards totaling approximately $75 million through competitive awards, sole source contracts, and interagency/ intergovernmental agreements. These awards will be matched with approximately $22 million in cash and other in-kind matching funds, thus providing approximately $99 million in total funding for PIER projects. The funding allocations are shown in Figure ES1.

PIER is now well established and fully functional in this early maturity stage for a research, development, and demonstration (RD&D) program. A summary of the major accomplishments of PIER during 2002 follows:

- The PIER program was linked with the Energy Commission's Renewables Energy Program through the staff of PIER's Renewables and Energy System Integration program areas.
- Collaborative research and commercialization activities were expanded with other RD&D institutions.
- A project and program benefits analysis based on the methodology used by the Gas Technology Institute (GTI) was initiated.
- Research contracts were prepared, consolidated, and streamlined.
- Legislation designed to allow streamlining of PIER administrative functions, particularly RD&D contracting, was signed into law by Governor Gray Davis.
- A new solicitation for technical support to PIER for the period of September 2001 through September 2004 was completed. The solicitation resulted in contract awards to three strong teams with a total of 510 experts in specific aspects of energy, science, and technology.

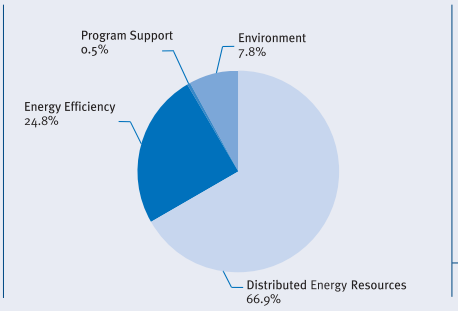

Figure ES1
PIER Program
Project
Allocations
1998 – 2002

Benefits from the PIER Commercial Successes

The PIER program began in 1998. Since then, $254 million has been encumbered for research contracts and program management costs. By the end of 2002, approximately half of the encumbered funds had been disbursed. A review of PIER contracts completed through 2002 revealed a total of 20 commercialized products with projected benefits of $221 to $576 million. Based on disbursements through 2002, the benefit-to-cost ratio is between two and five to one. Calculated benefits are based on net present value lifecycle cost savings for products introduced during their first five years of commercial availability. The range of benefits reflects uncertainties in the performance and sales projections for the products.

When compared to other RD&D organizations with similar mandates, the PIER program is highly successful. For example, the Gas Research Institute (GRI) demonstrated an impressive track record in producing commercially viable products and in creating benefits for the gas ratepayer over the years, producing over 500 commercially successful products from 1978 through 2001 and consistently documenting benefit-to-cost ratios well over one. The GRI has published annual evaluations of the benefits of its commercially successful products since 1985. The data obtained from the Gas Technology Institute, GRI's successor, show that GRI claimed 10 commercially successful products at the end of its fifth year of operation. PIER, with its 20 commercially successful products at the end of its fifth year of operation (see Figure ES2), compares quite favorably with GRI's experience. The GRI's disbursements during its first five years were approximately $354 million in nominal dollars or $621 million in constant 2002 dollars, compared to approximately $125 million in disbursements for PIER, making PIER's productivity even more impressive.

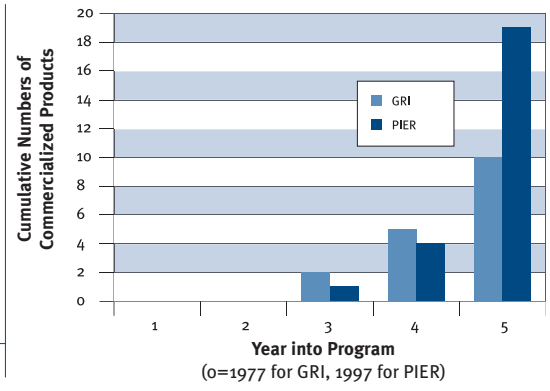

Figure ES2
Comparison of PIER and GRI Early Product Introduction Histories

Emerging Products and Technologies: Success Stories

Since the average time from start to finish for a research project is slightly over three years, some commercially promising energy products and technologies are just beginning to emerge from the PIER RD&D cycle. Some of the more exciting products are as follows:

- A compact fluorescent table/desk lamp that uses up to 70 percent less energy than units with incandescent or halogen bulbs.
- A ventilation unit that can significantly reduce air conditioning and peak load demand through night ventilation cooling.
- A laboratory fume hood that reduces air flow by up to 70 percent, compared to standard fume hoods, resulting in about $1,000 in energy savings per hood and 360 gigawatts of energy statewide each year.
- A more efficient power cycle that replaces conventional water with a mixture of ammonia and water, resulting in efficiency gains of up to 50 percent in geothermal plants and 20 percent in coal-fired plants.
- A small-scale gas turbine that lowers emissions of nitrogen oxides (NOx), carbon monoxide (CO), and unburned hydrocarbons to below 2 ppm, a significant reduction from the conventional 15 ppm.
- An electricity interconnection standard that streamlines the grid interconnection process for distributed generation technologies in California, thus lowering overall energy costs, improving power quality, and reducing power demand.

- A catalytic combustion system that prevents nitrogen oxides from forming in gas turbines as an air pollution prevention measure.
- Several products that will help transform the electricity grid to an automatic, switchable network. The projects are three grid-reliability software prototypes, new graphic-geographic monitoring displays, prototype loop flow monitoring and management software, and validated stability nomograms.
- A photovoltaic (PV) rooftop solar collector system that not only generates electricity but also provides insulation for the building, reducing heating and air conditioning costs and extending the life of the roof.
- Improved kitchen exhaust systems that help restaurant owners improve indoor air quality, energy efficiency, and affordability of their operations.
- A method for identifying and reducing power quality problems within the food processing industry, which will lessen the industry's susceptibility to power supply interruptions and result in cost savings.

Products readied for market but not yet commercially successful include the following: (1) several water treatment technologies included in the design of new water treatment facilities that the Metropolitan Water District will construct over the next two to three years, (2) a sensor to measure soil density and moisture content expected to be incorporated into tillage equipment of a major farm equipment manufacturer, (3) several environmental studies of the causes for and approaches to reducing financial costs of wildlife impacts on power facilities, and (4) an obstacle detection device to be incorporated into a boring tool manufacturer's line of equipment. As these technologies enter the market, California electric ratepayers will realize additional benefits from their investment in PIER.

Table ES1 list the PIER RD&D products commercialized through 2002.

Residential and Commercial Buildings End-Use Energy Efficiency

- Berkeley Lamp
- Commercial Kitchen Ventilation
- Particulate Emissions Measurement for Unhooded Restaurant Appliances
- Revised Residential Framing Factors
- HVAC Duct Sealing Technique for Small Commercial Buildings
- Allowable Placement of Roof/Ceiling Insulation in Nonresidential Buildings
- Requirements for Skylight Use in Low-Rise Residential and Commercial Buildings
- Goettl Comfortquest Gas Heat Pump
- Real-Time Energy Management and Control Systems

Industrial/Agricultural/Water End-Use Energy Efficiency

- Cast Metal Industry Electricity Consumption Study
- Poultry Rinse Recycling

Renewable Energy Technologies

- NOx Control in Biomass-Fueled Boilers with Natural Gas Cofiring
- PowerGuard® Solar PV System for Flat Roofs

Environmentally-Preferred Advanced Generation

- Catalytica Xonon® Catalytic Burner

Energy-Related Environmental Research

- Low NOx FIR Burner for Gas Boiler

Energy Systems Integration

- DG Interconnect Hardware
- Real-Time Monitoring and Dynamic Rating System for Overhead Transmission Lines
- Interconnection Standards for Small Distributed Generators
- Improved Substation Seismic Design
- Required Utility Buildings Seismic Vulnerability

Table ES1
PIER RD&D Products Commercialized Through 2002

2002 PIER Program Highlights

The highlights for each program area are presented below:

The **Residential and Commercial Buildings End-Use Energy Efficiency** portfolio grew to $42 million, with approximately $35 million in active research contracts. In addition to managing the current portfolio, the PIER Buildings program initiated approximately $10 million in new research.

As the program matures, a number of research projects are beginning to achieve results. The PIER Buildings team has been actively involved in sharing its research results with the broader market to ensure that the public interest energy efficiency programs are well coordinated with the investor-owned utilities' (IOUs) efficiency program. As PIER research results are adopted into the market, these results are beginning to impact the marketplace in many diverse and significant ways as highlighted later in this document.

One example of PIER success is the recently completed project *Improving Energy Efficiency of Commercial Kitchen Exhaust Systems*. The project will lead to better kitchen ventilation system designs that reduce overall exhaust and replacement air rates, resulting in reduced energy costs. Many restaurant owners in the state are already implementing these findings and reaping the benefits.

Looking to 2003, the program staff anticipates initiating new work in several identified areas of need as well as bringing to fruition some of the ongoing research and facilitating the market transfer of the research results.

The **Industrial/Agricultural/Water (IAW) Energy Efficiency** sectors account for 30 percent of all the electricity consumed in California. These sectors are critical to California's economy and rely on an affordable, reliable, and sustained supply of energy and electricity. The PIER program seeks to improve the energy efficiency of the industrial processes, agricultural operations, and water and wastewater treatment plants by providing new technologies and techniques through RD&D. These sectors are also sensitive to the power quality and reliability of electricity supply. Therefore, in addition to improving energy efficiency, the program also strives to research, develop, and demonstrate technologies that help these sectors deal with power quality and power supply reliability issues.

In addition to issuing contracts for specific projects, the program staff has also engaged in a major effort to develop a sound analytical base for selecting industries and RD&D projects. The program focuses on a few industries, based on their energy use and sensitivity to energy costs, and then develops industry-specific technology development plans. To make these plans research responsive to industry needs, the PIER staff developed the plans in collaboration with the industrial end-users.

In the **Renewable Energy Technologies** program area, the major focus of 2002 was implementing and managing the $32 million awarded to three program contracts during 2001. These efforts will result in numerous accomplishments and be valuable in meeting the goals established in California's new Renewable Portfolio Standard (RPS). In particular, PIER Renewables staff initiated a strategic value analysis effort that can serve as a road map for developing renewables between now and 2017, which will help meet the state's electricity needs as well as provide significant environmental and local community benefits. Projects from the three contracts will deliver renewable technologies that can be deployed in the near- and mid-term to help achieve the RPS goals. In addition, new assessment and evaluation tools have been developed that will enable renewable project developers and California communities to assess their renewable inventories and the feasibility of using renewables to meet their

needs. In all of these cases, strong collaborative working relationships have been developed to ensure that PIER funds are highly leveraged, that developed products are market connected, and that the program efforts provide significant public benefits to California's electricity customers.

The **Environmentally-Preferred Advanced Generation (EPAG)** team funded eight projects in 2002. Six of these were based on two solicitations released in 2001. Four projects were from the first solicitation, which targeted fuel cells, microturbines, small turbine generators, and hybrid systems that include a fuel cell or a turbine, along with associated technologies. Two projects were from the second solicitation, which targeted atmospheric emission reductions and efficiency improvements from reciprocating internal combustion engines. Of the remaining two projects, one was for the commercialized demonstration of a combined heat and power industrial gas turbine at a state facility, and the other was a jointly funded effort with the DOE to complete engineering and economic studies to install combined heat and power technologies at three separate federal facilities in California. In addition, the EPAG team is facilitating the installation of fuel cells and other distributed generation technologies through cooperation with other state agencies, the Association of State Energy Research and Technology Transfer Institutions (ASERTTI), and DOE. The EPAG team is also co-funding projects with the Electric Power Research Institute and the Gas Technology Institute.

The **Energy-Related Environmental Research** group funded eight major projects to address high-priority environmental issues related to the generation, distribution, and transmission of electricity in the areas of aquatic resources, land use and habitat, air quality, and global climate change. The projects focused on increasing hydropower production and mitigating its environmental impacts, mitigating avian mortality from transmission and distribution structures, and developing and improving air monitors and short-range dispersion models to evaluate the air quality impacts of electricity generation. Climate change projects focused on identifying California carbon sequestration opportunities, enhancing in-state environmental monitoring, and updating the *Inventory of California Greenhouse Gas Emissions and Sinks 1990 – 1999*. All of these projects show significant potential to benefit California's environment, public health, electricity reliability, and/or economy.

The **Energy Systems Integration** program area conducts cross-cutting research critical to improving California's electricity infrastructure. With its system approach to identifying and pursuing initiatives, the program's mission is to develop an integrated infrastructure where electricity transactions are more effective, efficient, and reliable. The current research is focused in four areas: integrating distributed energy resources into the system, improving the efficiency and reliability of the transmission system, building an infrastructure for demand response to dynamic prices, and developing strategic, enabling technologies.

Oversight

The PIER management and staff are addressing the comments and recommendations expressed by the initial Independent Review Panel (IRP) in its March 2001 Final Report. In response to the Panel's comments, the PIER management convened technical review committees for each of the six technical program areas. These committees met between September and December 2002 to review specific program area issues, portfolios, collaborations, and future plans. Each committee submitted recommendations to assist in future PIER and program area planning.

A PIER Policy Advisory Council is available to assist PIER with program issues and future plans. The Council is composed of PIER constituents and

experts in various aspects of California energy policy. The PIER Policy Advisory Council members are listed in Attachment 2. This past year, members of the PIER Policy Advisory Council also participated in technical reviews of six specific program areas. The Energy Commission anticipates that a future PIER Policy Advisory Council meeting will be held to review the committee discussions and recommendations from the overall PIER perspective.

Future Program Directions

PIER Five-Year Investment Plan

The PIER Five-Year Investment Plan was developed as required by Assembly Bill (AB) 995 (Wright) and Senate Bill (SB) 1194 (Sher), signed into law in September 2000. The plan addresses how the Energy Commission will manage the PIER program from 2002 to 2006 and responds to issues raised by the PIER Independent Review Panel (IRP) in 2001. The PIER program areas and their funded projects are focused on developing solutions to the problems identified in the plan, which include the following:

- Electricity demand has been rising faster than supply.
- Rising peak demand threatens reliability and power quality.
- Balance is needed between energy needs and environmental protection.
- Market uncertainty and price volatility are impacting energy delivery and use.

The PIER program has a major emphasis on end-use energy efficiency and demand response programs, with half of its funds allocated to those programs. Energy efficiency and demand response were among the state's most effective tools for dealing with the electricity supply disruptions of 2001. Not only is energy efficiency often as cheap or cheaper than new supply, it also provides environmental and economic benefits. Because the Energy Commission believes that investing in RD&D on energy efficiency can lay the groundwork for steady decreases in the energy intensity of the state's economy, the Energy Commission and PIER management have decided, of the first $64 million allocated, $32 million will be for end-use energy efficiency and demand response projects, $24 million for energy supply programs, and $8 million for energy related environmental programs.

Because of the enactment date for SB 1038, funds accrued since January 2002 were not encumbered until January 2003.

As part of overall PIER planning, technical reviews were conducted for all six PIER program areas. The Technical Review Committee included well-known senior researchers and technology developers from the private sector, national laboratories, government, and academia. Their recommendations will be incorporated into future energy technology development initiatives through June 2004.

Concurrent with the Technical Review Committee's activities, the PIER program was developing new transparent program selection processes through the use of a decision analysis process developed by Argonne National Laboratory. As part of these activities, the four issue areas developed through the PIER Investment Plan were disaggregated to 11 issues to reflect the importance of particular issue areas, while also reflecting changes that have occurred since the plan was submitted in March 2001. The PIER program objectives were also modified to make better use of them as discriminators in the project selection process.

The PIER program has adopted a portfolio and budgeting approach to balance the risks, benefits to ratepayers, and timelines for various PIER activities and investments. To expand its effectiveness, the PIER program will continue to establish partnerships with other RD&D institutions.

Oversight

With the enactment of SB 1038 (Statutes of 2002), the Independent Review Panel is scheduled to be reconstituted within 90 days of the effective date of the law. Thus, by April 1, 2003, the Energy Commission will have developed a contract to commence this activity. Per SB 1038, as many of the previous Independent Review Panel members as possible should constitute the new panel. To this end, the California Council for Science and Technology will again be retained for empaneling and supporting the Independent Review Panel.

The Independent Review Panel will be charged with two major areas of responsibility. First, since the first Independent Review Panel made a series of recommendations in its March 2001 report to the Energy Commission, the new Independent Review Panel will be asked to review and evaluate the implementation status of those recommendations. Additionally, the new Independent Review Panel will be asked to evaluate trends of improvement or lack of improvement for the overall PIER program.

The new Independent Review Panel will also being asked to address other issues raised by the previous Independent Review Panel. These issues focus on the value and utility of RD&D carried out in a state agency. The issues include, but are not limited to, the long-term nature of RD&D, the inherent restrictions imposed in contracting and civil service, and the need to develop mechanisms to better inform state decision makers.

Per SB 1038, the interim report will be completed in January 2004.


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OVERVIEW of the PIER Program

A. BACKGROUND

In 1996, California adopted far-reaching legislation that deregulated much of the state's electric services industry (1996 Statutes, Chapter 854, hereinafter referred to as AB 1890). Article 7 of AB 1890 was enacted to ensure that the benefits obtained from important public purpose programs—such as public interest energy RD&D—would not be lost in the newly deregulated environment. As a result, starting on January 1, 1998, and extending through 2001, Public Utilities Code (PUC) Section 381 requires that California's electric investor-owned utilities collect at least $62.5 million to fund energy-related public interest RD&D activities "not adequately addressed by competitive and regulated markets." In September 2000, the Legislature passed and Governor Gray Davis signed into law SB 1194 (Sher) and AB 995 (Wright), extending the PIER program surcharge for an additional 11 years from January 2001 to January 2012.

In AB 1890, the Energy Commission is authorized to receive and administer these funds, as designated by the California Public Utilities Commission (CPUC) to conduct public interest RD&D, subject to administration and expenditure criteria. In 1997, the CPUC determined that at least $61.8 million should be transferred annually from the major IOUs to the Energy Commission for specified public interest energy research (D.97-02-014)*. These funds are subject to the administrative and expenditure criteria adopted by the Legislature in 1997 through SB 90, which are contained in Public Resources Code (PRC) Section 25620 et seq.

In September 2002, Governor Davis signed into law SB 1038 (Sher, Chapter 515, Statutes of 2002), which restated the goal of the PIER program and requires that the Energy Commission use a portfolio approach to achieve that goal. *"The goal of the program is to provide public value for the benefit of California and its citizens through the development of technologies which will improve environmental quality, enhance system reliability, increase efficiency of energy-using technologies, lower system costs, or provide other tangible benefits."* SB 1038 further requires the Energy Commission to establish and convene on a regular basis an advisory board composed of representatives from the Energy Commission, consumer organizations, environmental organizations, and electrical corporations to make recommendations guiding the selection of PIER programs and projects to be funded. The bill also requires the Energy Commission to report on the actual costs and results of projects compared to their expected costs and benefits.

B. FIVE-YEAR INVESTMENT PLAN

On March 1, 2001, the Energy Commission provided the Governor and Legislature with the Five-Year Investment Plan, 2002 Through 2006, for the PIER program as required by SB 90. Subsequent to SB 90, SB 1194 and AB 995, enacted in 2000, required the establishment of a second review panel to report its findings and recommendations to the Legislature and Governor in 2005 regarding the status of the program. In September 2002, the Governor signed into law SB 1038 authorizing the Energy Commission to use the adopted Five-Year Investment Plan to ensure compliance with the policies and provisions of Section 399.7 of the PUC in administering the public interest energy research, development, and demonstration programs.

The Five-Year Investment Plan addresses how the Energy Commission will manage the PIER program from 2002 through 2006 and responds to issues raised by the PIER Independent Review Panel (IRP)

* In 1998, a small IOU, Bear Valley Electric Company (also known as Southern California Water Company), sought and received CPUC authority to contribute $56,000 annually to the PIER program.

as a result of its 2000 and 2001 reviews. The plan provides the following integrated framework for the PIER program:

- Fundamental mission, objectives, and vision for implementing the PIER program.
- Operational definition of public interest energy research.
- The expected "California Energy Context" for the state's energy RD&D program, including demographics, high-technology sector, social values, air quality, water, and global climate change.
- Energy-related impacts to which this context will give rise in the future.
- Public interest RD&D strategies and activities to address California's energy problems based on RD&D gaps that need to be filled to meet priority California needs.
- Budget strategy and proposed budget for the PIER program.
- Steps the Energy Commission has taken to implement the IRP's suggestions.

The design and management of the PIER program have proceeded as conceived in the plan so that the goals established by AB 1890 and the Energy Commission's subsequent strategic plan (P. 500-97-007, June 1997) will be met.

C. PIER VISION

The California vision is to provide a clean, affordable, reliable, and resilient supply of electricity where "smart," efficient customers have energy choices that can meet their individual needs, and California's industries can grow and prosper. The PIER program will support and catalyze science and technology advancements by providing leveraged funding to establish California as the world leader in energy efficiency and clean, advanced energy technologies and systems.

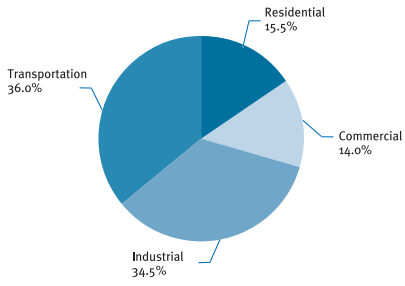

Figure 1
California Primary Energy Used by Sector (2002)

D. PIER MISSION

As its mission, the PIER program conducts public interest energy research that seeks to improve the quality of life for California citizens by developing environmentally sound, safe, reliable, and affordable electricity services and products. Public interest energy research includes the full range of RD&D activities that advance science and technology not adequately provided by competitive and regulated markets.

E. PIER PROGRAM OBJECTIVES

Following an internal review and decision analysis process, the PIER program objectives have been modified. The goal of strengthening California's economy remains an overreaching objective, which should be supported by all PIER program activities. The other objectives have been modified to better serve as discriminators for better selection of program areas. These are as noted below:

- Improving energy cost/value
- Improving the environment, public health, and safety
- Improving electricity reliability, quality, and sufficiency
- Addressing important RD&D gaps
- Providing greater choices for California consumers
- Connecting to near-term market applications

F. PIER PROGRAM RD&D AREAS

SB 1038 has modified some of the ways in which the PIER program is structured. The original law (SB 90) defined the subject areas in terms of technology areas:

- Residential and Commercial Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency (Process Energy)
- Renewable Energy Technologies
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration (ESI)

However, this program area structure is simply a tool in addressing California's energy issues. To this end, the enabling legislative language was modified to focus on issue resolution and problem solving. In meeting PIER program objectives, these issues must be addressed in many cases by technically cross-cutting RD&D.

The PIER program manager has clear authority to make decisions regarding the PIER program. There continue to be six teams led by staff experts called team leads, who report to the PIER program manager. Each team is responsible for planning and implementing the RD&D activities in his or her area to meet PIER program objectives and address California electricity issues.

In addition, the PIER program manager directs team leads to increase cooperation and collaboration between areas. This has led to a number of new initiatives in areas such as energy storage technology, demand response technology, and distributed energy resources.

The PIER program manager also requires greater substantive collaboration between the Energy Commission/PIER and other state agencies. This has proven to be effective in the technology development of low-emission gas turbines (California Air Resources Board) and renewables and terrestrial sequestration resource assessments (California Department of Forestry and Fire Protection). Collaborations are also increasing between the Energy Commission/PIER and the DOE in a number of end-use energy efficiency and distributed energy resources programs.

PIER has also received input from Technical Review Committees, composed of nationally known experts and Policy Advisory Council members. Current and future programs will continue to be reviewed and evaluated—both internally and externally—to ensure that the overall scope of the program continues to address and resolve important California energy issues.

G. ENERGY INNOVATIONS SMALL GRANT PROGRAM

The purpose of the Energy Innovations Small Grant (EISG) program is to study new, innovative energy solutions through an earlier and easier entrée to PIER support. The EISG program offers small businesses, nonprofits, individuals, and academic institutions grants up to $80,000 for proof-of-concept research projects that, if successful, will attract follow-on funding for a full development effort. This non-EISG follow-on funding comes from a variety of sources, including the mainstream PIER program, the DOE, the National Science Foundation, NASA, and the Department of Defense (DOD) Small Business Innovation Research(SBIR). Since EISG grants are awarded for feasibility research that will meet California's energy needs, the follow-on funding also serves California's interests, regardless of its source.

The EISG program offers up to four solicitations per year, with each solicitation open across the six PIER program areas. The program is funded at $3 million/year. In 2002, the Energy Commission conducted three solicitations and approved 27 grants totaling $2,009,528. Since program conception in September 1998, a total of 12 solicitation and award cycles have been completed, resulting in 108 grants approved by the Energy Commission.


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CURRENT STATUS of the PIER Program

A. IMPLEMENTATION OF THE PIER FIVE-YEAR INVESTMENT PLAN

The PIER program implements AB 1890, SB 90, AB 995, and SB 1194, the Energy Commission's RD&D strategic plan, and the Five-Year Investment Plan, 2002 Through 2006. These documents identify the essential state policies and objectives for energy-related public interest research. In turn, the results from the PIER program will provide input for developing future state energy policies.

In 2002, the PIER program implemented the 2000–2001 recommendations of its IRP and PAC. The IRP, consisting of eminent research experts, completed its review tasks when it issued its second report, *California Public Interest Energy Research, Independent PIER Review Panel Final Report*, in March 2001.

The topics covered in the Five-Year Investment Plan are presented in four chapters that address the following subjects:

- The PIER program's fundamental mission, operational definition and related criteria for public interest research, and a guiding vision for California's energy future
- The California Energy Context
- The major energy-related problems confronting California and a portfolio of integrated RD&D strategies for finding solutions through the PIER program
- The Energy Commission's approach and budget for funding future PIER projects and addressing the concerns of the IRP

The plan identifies elements of California's energy-related circumstances and trends, including deregulation, demographics, technological advances, economic conditions, social values, political factors, climate, and environmental factors. In particular, the plan highlights the following concerns:

- Rapid growth in demand, particularly peak demand, as a threat to reliability and power quality
- Need for balance between meeting energy needs and protecting the environment
- Market uncertainty and price volatility as they impact energy delivery and use

Four factors increase the necessity to advance science and technology specific to California's needs under deregulation: (1) reliable, affordable, and clean new supplies; (2) smarter energy transmission and delivery; (3) ways to use energy that are more efficient, clean, and economic; and (4) readily available information concerning the status and capability of the system and its environment. The PIER program is the public interest research response to meet these California needs.

The following is a summary of the Energy Commission's accomplishments at the PIER's program management level during 2002.

- Awarded 43 contracts for $74.5 million
- Developed three additional "success story" fact sheets that emphasize the productivity of the program
- Completed several intermediate goals in its staffing-up program, including filling all top supervisory positions
- Linked PIER with the Renewables Energy Program through the staff of PIER's Renewables and Energy Systems Integration program areas
- Expanded collaborative research and commercialization activities with other RD&D institutions
- Initiated a project and program benefits analysis based on the methodology used by GTI for its public interest RD&D activities

- Consolidated and streamlined preparation of research contracts in a special process under the title "SPARKEY." The team consists of a contract manager, representatives from the Contracts and General Counsel's offices, and a standing member of the SPARKEY group. All issues are identified and resolved in team meetings
- Reintroduced legislation designed to allow streamlining the PIER program administrative functions, particularly RD&D contracting, passed and signed by Governor Davis in 2002

Commercial Successes

The PIER program began in 1998. Since that time, a total of $254 million has been encumbered to research contracts and program management costs. Only about half of the encumbered funds have been disbursed through the end of 2002. A review of PIER contracts completed through 2002 revealed a total of 20 commercialized products with projected benefits of $221 to $576 million. Based on the estimated disbursements through 2002, the benefit-to-cost ratio is between 2 and 5 to one. For tangible products (hardware, software), "commercialized" means that the product is commercially available, economically viable without subsidies, and has been sold in its intended market. For the less tangible reports and other information products, "commercialized" means that the product has been used in a commercial enterprise or for a regulatory application and has generated demonstrable economic benefits to the users or the public. The list of 20 products determined to meet these commercialized requirements is shown in Table 1.

Benefits from these 20 commercialized products were calculated by projecting sales or applications of the products for five years after their commercial introductions. Benefits per application of the product were estimated by evaluating the savings (energy cost, first cost, maintenance cost, labor costs, etc.) per year accruing to a typical user who chose to use the PIER product rather than its most likely competitor. Any incremental costs required to use the PIER product rather than its competitor were subtracted from the cost savings. The resultant net savings per user were multiplied by the projected product sales for that year. Finally, the net present value of the savings for all products introduced during the first five years of product commercial use was calculated. The projected sales and the resultant benefits are both shown as ranges to reflect the uncertainties in the levels of projected use and to disguise any manufacturer proprietary sales forecasts. Because commercial applications of all the PIER products are just beginning, most sales estimates are still quite speculative at this time. Future evaluations will use actual sales data in place of projections to the extent possible. Benefits results are summarized in Table 2.

Numerous additional products have been readied for market, including several water treatment technologies that have been included in the design of new water treatment facilities that will be constructed by the Metropolitan Water District over the next two to three years; a sensor to measure soil density and moisture content that is expected to be incorporated into tillage equipment of a major farm manufacturer; several studies of the causes for and ways to reduce costs associated with power facilities impacted by avian collisions; and an obstacle detection device that will be incorporated into a boring tool manufacturer's line of equipment. It is likely that several of these market-ready products will be applied commercially at some time.

PIER completed its fifth year of operation at the end of 2002. That is a very short amount of time to realize commercial successes from an RD&D program. Comparing the length of time from project initiation to the first sale or application of a product commercially showed that the 20 projects evaluated took 3.2 years to succeed commercially. Thus, the typical product resulted from a PIER project that was initiated in 1998 or 1999. Contracts initiated later than 1999 simply have not had sufficient time for completion of RD&D and commercialization of products.

Residential and Commercial Buildings End-Use Energy Efficiency:
Berkeley Lamp. A table lamp with two compact fluorescent bulbs designed to operate independently to provide task lighting, indirect lighting, or a combination of the two. This lamp is designed to provide a high-efficiency alternative to overhead lighting in offices and torchiere lighting in residences. Marketed by The Light Corporation.
Commercial Kitchen Ventilation. Guidelines to install hoods and makeup air ducting in commercial kitchens to minimize the undesirable interactions between the flow of makeup air and the flow of air contaminated by cooking vapors into the hood. Proper location and design of makeup air ducts allows greatly reduced hood air flows, which reduces hood fan power and losses of conditioned air from the kitchen. Information disseminated by the Pacific Gas and Electric (PG&E) Food Service Technology Center.
Particulate Emissions Measurement for Unhooded Restaurant Appliances. Protocol and techniques for measuring the emissions of particulate matter from restaurant appliances. A standard protocol is provided to determine the need for a hood for a specific appliance, and this protocol is recognized by the UL-Witness Test. The measurement technique is the basis for a test cell and testing service for appliances and is offered by the PG&E Food Service Technology Center.
Revised Residential Framing Factors. California Title 24 Building Efficiency Code updated default framing factors for residential new construction. The framing factors (area of window and door frames divided by total wall area) could be used in energy calculations to determine the required level of wall insulation. Updated framing factors are higher, resulting in more required wall insulation and reduced energy use.
HVAC Duct Sealing Technique for Small Commercial Buildings. Update to Title 24 providing a standard for sealing HVAC ducts in small commercial buildings. The new requirements are based on the success of an aerosol spray technique for the internal surface of the ducts. AeroSeal offers the spray technique as a commercial service.
Allowable Placement of Roof/Ceiling Insulation in Nonresidential Buildings. Update to Title 24 requiring that ceiling insulation for commercial buildings be placed in contact with roof deck (interior or exterior) in most new buildings. Eliminates problems created by building renovations where the integrity of the insulation is frequently compromised.
Requirements for Skylight Use in Low-Rise Residential and Commercial Buildings. Update to Title 24 requiring the use of skylights with timers or light sensor controls in new commercial buildings with 25,000 square feet of open area directly under a roof and a ceiling height of 15 feet or more.
Goettl Comfortquest Gas Heat Pump. Vapor compression heat pump driven by a natural gas engine and offered in sizes between 15 and 30 tons. Offers a low electricity use option for areas where electricity supplies are extremely constrained.
Real-Time Energy Management and Control Systems. Lawrence Berkeley National Laboratory (LBNL) developed an information monitoring and control system concept to track the performance of large commercial HVAC equipment, diagnose troubles, and identify actions to increase operating efficiency. The Silicon Energy Corporation and PowerNet Software incorporated the concept into commercial energy management and control software.

Table 1
PIER RD&D Products Commercialized Through 2002

Industrial, Agriculture, and Water End-Use Energy Efficiency:

Cast Metal Industry Electricity Consumption Study. A study of energy utilization for metal melting operations in California foundries, consisting of a foundry energy survey to collect information and profile California metal melting operations through an examination of energy usage and cost savings strategies. The study's technical recommendations will result in savings in melting energy usage when implemented. The study was distributed to virtually all foundries in California.

Poultry Rinse Recycling. A water recycling system for chilled rinse water used in poultry processing plants. Specifically, the new recycling system eliminates the need for chlorine in water and replaces the daily chilled water by using ozone to kill bacteria and hollow membrane filtration to remove foreign matter.

Renewable Energy Technologies:

NOx Control in Biomass-Fueled Boilers with Natural Gas Cofiring. The Gas Technology Institute's adapt-to-market technology for gas cofiring of biomass-fueled boilers. Gas cofiring in the 5–15% gas range improves the power generation economics, reduces NOx and CO emissions, and allows plants to operate at increased capacity compared to previous NOx-related limitations. This technology increases the plant turndown ratio and improves the response of the electrical output to changing peak loads.

PowerGuard® Solar PV System for Flat Roofs. PowerLight's PowerGuard® is a complete, pre-engineered system, easy to install and practically maintenance free. The patented, lightweight photovoltaic roofing assembly generates clean, reliable electricity while reducing the building's energy load and peak demand costs. Available in flat or angled tile arrays. Projected cumulative sales in California of 5 to 10 megawatts (MW) through 2006.

Environmentally-Preferred Advanced Generation:

Catalytica Xonon® Catalytic Burner. Catalytic combustion burner for small gas turbines, designed to reduce NOx emissions to 2 parts per million (ppm). Several turbine manufacturers are integrating this burner into gas turbine systems.

Energy-Related Environmental Research:

Low NOx FIR Burner for Gas Boiler. A forced internal recirculation (FIR) burner to use in natural gas boilers, developed by DOE and the Gas Technology Institute, and now being incorporated into a boiler line by Detroit Stoker. The new burner uses several techniques, including premixed stoichiometric combustion, internal recirculation of combustion products, and staged combustion with enhanced combustion uniformity. The advancement reduces both NOx emissions (to < 9 vppm) and CO emissions (to < 40 vppm) without sacrificing efficiency.

Energy Systems Integration:

DG Interconnect Hardware. This hardware is an inexpensive, which complies with Rule 21, solid state interconnection system to control grid-connected distributed generation systems. The interconnection hardware is offered commercially by EnCorp, Inc. as the EnpowerTM-GPC.

Real-Time Monitoring and Dynamic Rating System for Overhead Transmission Lines. Designed to replace the current overly conservative power limits that are based on worst-case conditions

Table 1
PIER RD&D Products
Commercialized
Through 2002
(continued)

and lead to overestimating the maximum thermal sag of the lines on hot days with little wind. The PIER program has developed a new system, and it was applied by the CAISO on the Path 15 segment connecting northern and southern California transmission systems.

Interconnection Standards for Small Distributed Generators. A common set of simplified procedures for reviewing and approving applications for grid-connected distributed generators. The results to date (FOCUS-I) apply to cases where the DG unit is connected to the grid but does not supply power to the grid. A simplified review process has been developed that allows DG applicants to bypass several stages of the previous review process if they meet certain minimal requirements, resulting in a labor saving by the applicants and utility reviewers.

Improved Substation Seismic Design. This laboratory simulation of interconnected electrical substation components under earthquake condition demonstrated that certain types of interconnections (rigid or spring-loaded) could create stresses on insulators or forces on transformers and other equipment that led to more damage than would occur for isolated equipment. It has led to changes in substation design guidelines and in component selection that would reduce the damage from an earthquake.

Reduced Utility Building Seismic Vulnerability. Development of new building structural performance simulation tools for use by utilities located in earthquake zones. Designs were developed that ensure employee safety and reduce the likelihood of outages caused by building damage without overly conservative assumptions. A comparison of old and new approaches to retrofit existing buildings has demonstrated that significant savings will accrue to PG&E as a result of less conservative approaches to retrofitting three common building types.

Table 1
PIER RD&D Products Commercialized Through 2002 (continued)

Product Name	Year of First Use	Sales or Applications in First Five Years	Range of Benefit ($ M)
Residential and Commercial Buildings End-Use Energy Efficiency:			
Berkeley Lamp	2001	5,000 to 60,000	$2 to 23 million
Commercial Kitchen Ventilation	2002	2,000 to 10,000	$14 to 71 million
Particulate Emissions Measurement for Unhooded Restaurant Appliances	2001	Not tracked	< $1 million
Revised Residential Framing Factors	2005	100,000 to 200,000	$2 to 6 million
HVAC Duct Sealing Technique for Small Commercial Buildings	2005	50 to 175 million sq. ft.	$40 to 140 million
Allowable Placement of Roof/Ceiling Insulation in Nonresidential Buildings	2005	18 to 30 million sq. ft.	$67 to 112 million
Requirements for Skylight Use in Low-Rise Residential and Commercial Buildings –	2005	80 to 175 million sq. ft.	$67 to 150 million

Table 2
Benefits of PIER RD&D Products Commercialized Through 2002

Product Name	Year of First Use	Sales or Applications in First Five Years	Range of Benefits ($ M)
Goettl Comfortquest Gas Heat Pump	2002	< 100	< $1 million
Real-Time Energy Management and Control Systems	2002	Insufficient data	Insufficient data
Industrial, Agriculture, and Water End-Use Energy Efficiency:			
Cast Metal Industry Electricity Consumption Study	2001	5% to 50% CA market	$0.5 to 5 million
Poultry Rinse Water Recycling	2002	10% to 50% of market	$1 to 5 million
Renewable Energy Technologies:			
NOx Control in Biomass – Fueled Boilers with Natural Gas Cofiring	2002	2 to 7 boilers	$0.2 to 1 million
PowerGuard® Solar PV Systems for Flat Roofs	2001	5 to 10 MW	$30 to 80 million (gross revenues)
Environmentally-Preferred Advanced Generation:			
Catalytica Xonon® Catalytic Burner	2002	50 to 250 MW	$5 to 25 million
Energy-Related Environmental Research:			
Low NO_x FIR Burner for Gas Boiler	2002–2003	5 to 15	< $1 million
Energy Systems Integration:			
DG Interconnect Hardware	2001	Insufficient data	Insufficient data
Real-Time Monitoring and Dynamic Rating System for Overhead Transmission Lines	2000	Insufficient data	Insufficient data
Interconnection Standards for Small Distributed Generators	2002	500 to 2,000 kW	$4 to 16 million
Improved Substation Seismic Design	2002	N/A	$1 to 2 million
Reduced Utility Building Seismic Vulnerability	2002	100 buildings	$15 to 20 million

Table 2
Benefits of PIER RD&D Products Commercialized Through 2002 (continued)

B. 2002 PIER PROGRAM HIGHLIGHTS

The overall PIER funding objectives are implemented by selecting and supporting projects in the following six PIER program areas and the EISG.

RESIDENTIAL AND COMMERCIAL BUILDINGS END-USE ENERGY EFFICIENCY

2002 Progress Update

In 2002, the PIER Buildings portfolio grew to $42 million with approximately $35 million in active research contracts. In addition to managing the current portfolio, the PIER Buildings program initiated new work in the areas of cool colored roofing materials, advanced windows, building vulnerability mitigation, underfloor air distribution systems, new energy efficient lighting, residential retrofit commissioning, standby power, and low-energy cooling systems.

Research was completed in 2002 (or nearly completed) in the following areas:

- Development of a Conceptual Design Energy Analysis Tool
- Improving Energy Efficiency of Commercial Kitchen Exhaust Systems
- Next Generation Power Management User Interface for Office Equipment
- Development of a Priority Agenda for Energy-Related Indoor Environmental Quality Research
- Standby Loss Scoping Study, Phase 1

As the program matures, a number of research projects are beginning to achieve results. The PIER Buildings team has been actively involved in sharing its research results with the broader market to ensure that the public interest energy efficiency programs are well coordinated with the IOUs efficiency program. Examples of successful market actions initiated this year for PIER research projects include:

- California utility demonstrations of successfully developed PIER technologies to validate performance and bridge the path to commercialization. Examples of PIER technologies demonstrated through the utilities' emerging technology programs include:
  - NightBreeze, a ventilation unit that can significantly reduce air conditioning and peak load demand through night ventilation cooling
  - Commercial kitchen exhaust ventilation strategies (highlighted as a success story later in this report)
  - Heat pump water heaters with improved efficiencies and simplified field installation requirements
- Partnerships with industry—particularly builders, building owners, and manufacturers—to ensure the market relevance and facilitate the market adoption of research results. Examples include:
  - Demonstrations of NightBreeze by two major California builders
  - Adoption of new energy-efficient commercial kitchen exhaust designs by numerous fast food restaurant chains in the state
  - Development of improved hood designs and improved variable-speed exhaust systems by manufacturers based on research findings related to the commercial kitchen exhaust systems
- Integration of research results into proposed Title 24 building standards in the following areas:
  - Non-residential duct sealing and insulation
  - Verification and quality assurance process to improve performance of small HVAC systems and controls
  - Outdoor lighting regulations
  - Daylighting
- Coordination with the Institute of Electrical and Electronics Engineers (IEEE) to develop a draft standard for power controls user interfaces that help in market adoption of consistent interfaces and result in reduced energy use for equipment such as desktop/laptop computers
- Development of plans for utility-sponsored training classes related to PIER research results through the utility energy center

- Numerous conference presentations highlighting PIER research results, including papers presented at conferences sponsored by the American Council for an Energy Efficient Economy (ACEEE); American Society for Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE); the Illuminating Engineering Society of North America (IESNA); and many others.
- Articles published in trade journals highlighting PIER research

These initiatives are just some of the diverse and significant ways PIER research results are beginning to impact the marketplace.

2002 RD&D Awards

In the *2001 PIER Annual Report Outlook*, the PIER Buildings team identified plans to fund work in the development of cool colored roofing materials, new efficient lighting products, advanced windows, and a California optimized cooler. All of these projects have been successfully initiated and are making good progress, with the exception of the California optimized cooler. That work has been deferred to 2003 due to resource constraints. However, it is still considered a priority project and the PIER Buildings team anticipates initiating this work in the second quarter of 2003. A summary of the key projects initiated in 2002 follows.

Development of Cool Colored Roofing Materials

White roofs have been shown to significantly reduce heat gain in both residential and commercial buildings. However, in residential applications, white roofs are generally not acceptable to homeowners from an aesthetics perspective, in spite of the energy-saving potential. This research will develop energy-efficient roofing products in marketable colors. Specifically, blends of different "cool" materials will be developed to produce the colors desired by homeowners. Testing to quantify how cool roofing materials perform over extended periods of time in the field will be conducted to validate performance. Manufacturing partners will be particularly critical to ensure that specific market products are produced. The successful outcome of this research will therefore lead to widespread adoption of cool colored roofing materials, which will lower the demand for cooling during the hot season, extend the life of roofing materials, and reduce the rate of smog formation by lowering ambient air temperatures.

Development of Advanced Windows

Electrochromic glazings offer dynamic and responsive control of the thermal and optical properties of the building facade. However, significant questions of technical, engineering, architectural, and general public interest remain to be answered. This proposed effort will be a collaborative effort supported by the Energy Commission, the DOE, and the Environmental Protection Agency (EPA) to develop, demonstrate, and evaluate integrated electrochromic window systems that will yield benefits of national interest including energy efficiency, peak demand reductions, and comfort. In addition, it will demonstrate, validate, and quantify the technical performance of these systems in buildings, and develop the information products needed to support its effective use with minimal risk and performance uncertainties.

Building Vulnerability Assessment

People spend upwards of 90 percent of their time indoors, typically in places of employment or in residences. Buildings have a significant effect on the consequences of a chemical or biological agent attack, or the release of a toxic agent due to an accident. This research project will help in understanding the vulnerabilities of buildings and the relationship of these vulnerabilities to the building's energy systems. It will also estimate the consequences of deliberate or accidental toxic agent

releases and, more important, identify options for mitigating or eliminating them. A set of guidelines and assessment procedures that will aid private sector consultants and facility managers in assessing and reducing building vulnerabilities will result from this research.

Energy Performance of Underfloor Air Distribution Systems

Underfloor air distribution (UFAD), a method of delivering space conditioning in offices and other commercial buildings, has begun to experience rapid growth in North America during recent years. These systems have significant potential for both reducing energy use as well as improving occupant comfort and productivity. However, standardized methods and guidelines for designing these systems or optimizing their performance do not exist. The goal of this project is to develop simulation software that can be used by design practitioners to calculate the energy performance of UFAD systems and to compare it to that of conventional systems. The availability of such a tool will help UFAD technology achieve its full potential by enabling the design of UFAD systems that are energy efficient, intelligently operated, and effective in their performance. In California, with its mild climate and numerous high-tech businesses with their typically extensive use of information technologies and high churn rates, UFAD systems are particularly well suited and their market penetration is expected to be significantly higher than the national average.

Lighting Research Program

The purpose of this contract is to conduct a systematic lighting research program (LRP) that creates new lighting technologies and products that can save energy, reduce peak demand, and reduce pollution for the citizens of California. The integrated program is composed of one administrative element and five technical elements, including a very critical market connections element that will greatly facilitate the transfer of the research results to the market via end-users, manufacturers, designers, standards developers, and others. In all, the program includes a total of 18 research projects.

Element 1 *Program Administration*. This first element is designed to provide contractual, technical, and financial leadership to the program; to insure that the Energy Commission is involved in these processes; and to insure that the Energy Commission receives monthly and annual reports of project activities.

Element 2 *Advanced Lighting Technologies*. Recently, solid state lighting technologies have made breakthroughs that allow light emitting diodes (LEDs) to create white light and have increased the efficiencies for cost-effective applications such as traffic lights. LED lighting applications for commercial and residential building use are just emerging. This element focuses on technologies and products that use LEDs and research for improving LED performance and reducing costs. Products that will result from this research include energy efficient porch lights, white light-emitting diodes, and specialized LED luminaires.

Element 3 *Demand Responsive Lighting Systems*. Projects in this element will develop advanced lighting control systems with improved photosensor technology, integrated with occupancy sensors, and building lighting systems. Ballast technologies and controls system improvements will be developed to reduce the cost for demand reduction systems. These systems will apply to the retrofit market as well as the new construction market.

Element 4 *Advanced Lighting Luminaires and Systems*. Different manufacturers and companies usually sell lighting systems as a set of components

that are provided to create a complete lighting system. This requires a custom design and installation of the system. This element will develop integrated lighting systems that will reduce costs, complexity, and energy use. Specific products that will be developed from this research include energy-efficient hotel/institutional bathroom lighting systems; integrated energy-efficient high-end residential lamps; cost-effective high-efficiency compact fluorescent (CFL) downlight packages; and portable task/ambient lighting luminaires with occupancy and other controls for office, home office, and commercial applications.

Element 5 *Lighting Performance Metrics, Codes, and Standards*. This element will focus on the development of metrics to better characterize performance, and codes and standards applications to facilitate market adoption of research results. Specific needs/opportunities to be addressed in this element are the development of bi-level stairwell fixture performance; evaluation of electronic ballasts and related controls for high-intensity discharge lighting systems; development of low-glare outdoor retrofit luminaires; and enhancement of a digital addressable lighting interface (DALI) lighting control device standard.

Element 6 *Market Connection*. Too often RD&D projects succeed technically but fail to reach the market or find commercial success. This program element is an innovative centralized program-wide approach to improve market focus and thereby increase the ultimate commercial viability of the program's technology products. It provides all the program's RD&D projects with consistent product assessment and commercialization recommendations from key lighting market experts; assists and advises the developers of the most market-ready products in the transition from RD&D to production and market entry; and provides a consistent set of product-descriptive materials for use in industry reference and public education by the Energy Commission, individual product developers, and other market factors.

Residential Retrofit Commissioning

While research has demonstrated techniques to improve residential building efficiency, development is needed to incorporate these techniques into practical business models for contractors. This research project will build upon past PIER research that analyzed residential commissioning strategies and will take the next step in developing practical commissioning protocols based upon sound business practices for residential retrofit applications. In addition, the residential retrofit practices will be tested by contractors, and home energy performance will be validated. This important next step is needed to overcome current barriers to residential retrofit commissioning.

Standby Power Study

An increasing amount of electricity is used in the standby mode for office equipment, consumer electronics, household appliances, safety equipment, and other miscellaneous products. Current estimates indicate that standby energy loss is significant, contributing to about 10 percent of total electricity use in California homes. This project was initiated to better understand the scope of the problem and determine what steps need to be taken to begin resolving the issue. The research team identified specific opportunities to mitigate this problem via improvements to power supplies, low-power circuitry, clearer user interfaces, and the development of new efficient technologies. As a follow-on to this effort, the PIER Buildings team will evaluate the study results and target a solicitation in 2003 to address the problems that public interest energy research can most significantly impact.

Low-Energy Cooling Systems for Commercial Buildings

This project will fill an information gap that

currently exists related to low-energy cooling systems and enable the Energy Commission to make informed decisions in the future relating to design issues and research needs. It will assess the effectiveness of low-energy cooling strategies presently in operation in California and identify deficiencies in current tools, barriers to adoption, what is being used, and what isn't. The research team will solicit input from designers to determine their needs and how the tools can be improved to meet them. The project will also characterize the costs, performance, strengths, and weaknesses of low-energy cooling systems in commercial buildings, as well as the methods used to design these systems. These goals will be accomplished by (1) conducting case studies of low-energy cooling systems in commercial buildings in California, or in climate regions comparable to those found in California, and (2) evaluating the methods used to design low-energy cooling systems. This activity will complement current PIER-funded RD&D where computer models are being developed to estimate the thermodynamic behavior of low-energy cooling systems.

Success Story

Improving Energy Efficiency in Commercial Kitchen Ventilation Systems

Results from recently completed research have the potential for significantly improving the way exhaust systems in restaurants are designed throughout California.

By combining a unique method for visualizing exhaust flows with findings regarding optimizing how replacement air is introduced, designers can help restaurant owners improve the indoor air quality, energy efficiency, and affordability of their operations.

The recently completed research project *Improving Energy Efficiency of Commercial Kitchen Exhaust Systems* explored a number of energy and design issues related to capture and containment of cooking emissions. The findings of the study will result in better kitchen ventilation system designs that reduce overall exhaust and replacement air rates. This means reduced fan energy costs and, in some cases, reduced cooling and heating costs. Some restaurant owners in the state are already implementing these systems and reaping the benefits.

Background

A universal concern regarding the commercial kitchen space is having an effective ventilation system. A large portion of kitchen ventilation planning is dedicated to properly exhausting cooking effluent. Appliance layout and the energy input are evaluated, hoods are located and specified, the ductwork size and routing are determined, and exhaust fans are specified to remove the proper volume of air. Unfortunately, much less time is usually dedicated to planning how the exhausted volume of air will be replaced, although an air balance schedule is commonly used to indicate the source of the makeup air.

Overlooking the details of the replacement-air delivery system can have a negative impact on the performance of an otherwise well-designed kitchen. Cross drafts and high air velocities due to improper introduction of the makeup air can result in a failure of the hood to capture and contain effluent from the appliances. This effluent spillage may include convective heat, products of natural gas combustion (carbon dioxide, water, and potentially carbon monoxide), and products from the cooking process, such as grease vapor and particles, odors, water vapor, and miscellaneous hydrocarbon gasses. The overall commercial kitchen ventilation issues include indoor air quality, fire prevention, safety, employee comfort, equipment first costs, and energy operating costs. These costs often compete with the ventilation issues for foodservice industry and operator attention.

Key Findings

- Hood type has a significant influence on the exhaust rate providing full capture and containment (C&C). Island and wall-mounted canopy hood types require more than twice the exhaust rate of the proximity hood type for the same appliances and operating conditions.
- Supplying large percentages of replacement air within the vicinity of an exhaust hood may interfere with C&C.
- The internal design of integrated supply plenums and air outlets (air curtain, front face, and short circuit) influences discharge velocity rate and velocity uniformity, which in turn, impacts hood performance.
- For canopy hoods, greater hood overhang can improve C&C performance.
- Side panels permit a reduction in the C&C exhaust rate and provide a method to mitigate cross draft problems in existing or new kitchens.

Market Success

The ultimate indicator of research success is adoption of the results in the marketplace. The impact these research findings will have on the marketplace is evident by the high level of industry interest and involvement. Both during the research phase, and now, as early commercialization is initiated, there has been active engagement from manufacturers, designers, utilities, and restaurant owners throughout the state.

The principal investigators for the project, Fisher-Nickel, Inc. and Architectural Energy Corporation, have already applied the research results in projects with their clients. One full-service restaurant already has an improved ventilation system using a backwall supply for replacement air. Several other projects are in the design phase.

Recent proprietary testing at the Commercial Kitchen Ventilation Laboratory for kitchen manufacturers Captive Aire, Greenheck, and Randell, revealed that the results of this Energy Commission–sponsored study are being used as a foundation for further development.

The design guide developed from the research results has been distributed at a number of seminars and workshops at PG&E's Pacific Energy Center, Southern California Edison's Customer Technology Assistance Center, and Southern California Gas' Gas Technology Center. The estimated total number of participants at these seminars was 75. Fisher-Nickel will continue to distribute the design guide at its Commercial Kitchen Ventilation seminars under its Energy Efficiency in Commercial Food Service Local

Full Capture with Side Panels

Wall Canopy Hood Showing Spillage

Program sponsored by the California Public Utilities Commission. Captive Aire and Greenheck are distributing the design guide to customers in California and across the country through seminars and direct mailings.

Southern California Edison plans to distribute the design guide to food service operators, designers, and mechanical engineers within its service territory. Edison also is planning another design guide that elaborates on the design process needed to take advantage of the research results.

The Emerging Technology Coordinating Council (comprised of San Diego Gas & Electric, Pacific Gas & Electric, Southern California Edison, Southern California Gas, and the California Energy Commission) has started a commercial kitchen ventilation demonstration program based on the research results from the project. Four sites have been earmarked (including two Applebees, an Islands, and a Panda Express) and two to four more locations are likely to be identified. Several replacement air designs as well as improved hood designs and variable speed exhaust systems will be demonstrated.

Estimated Energy Savings

The Energy Commission estimates that in the year 2000, food service facilities accounted for about 145 million square feet of commercial floor space, 5,960 gigawatt-hours (GWh) of electric use, and 929 MW of demand. Growth in restaurant floor space may add an additional 33 million square feet by 2012.

Based on an estimated 225 million cubic feet per minute of exhaust air from existing food service facilities in the state of California, exhaust and replacement air fan energy uses about 460 GWh and 90 MW of demand. Applying the research results would lead to a reduction in electric energy use and demand of about 69 GWh and 14 MW, assuming an across-the-board reduction in exhaust and replacement air fan energy of 15 percent. These savings do not include cooling and heating energy associated with replacement air. Larger reductions in fan energy, up to 50 percent, are possible with innovative new designs.

This far-reaching research will impact restaurants from fast food chains to large commercial and institutional food facilities and improve the indoor air quality, energy efficiency, and affordability of their operations in the years ahead.

Outlook

In 2003 the PIER Buildings team will initiate collaborative projects in several major areas in addition to initiating a number of specific projects in areas of identified need to address California-specific energy issues. Partnerships will be formed with the DOE, national laboratories, and other state and federal agencies as well as private-sector manufacturing partners. These collaborations will build upon past research already completed by one of the participating entities where possible and will bring together public and private partners to ensure that the resulting research products are responsive to market needs and carried forward into the marketplace. Some of the collaborative activities and follow-on research the Buildings team anticipates initiating in 2003 include the following:

Programmatic Contracts Related to Indoor Environmental Quality

In 2002, the PIER Buildings program released a programmatic solicitation in the area of indoor environmental quality (IEQ). The focus of the solicitation was based on both a national research agenda developed in this area in 2002 and on specific California issues. Specifically, the solicitation focuses on improving indoor environmental quality in buildings while minimizing energy use in the following areas: improving designs for heating, ventilation, and cooling systems; improving the accuracy of

ventilation rate assumptions and the effectiveness of ventilation control strategies; developing better tools for detection, diagnosis, and mitigation of IEQ problems; and developing useful consumer information products to help guide informed decision making. Through this research, the Energy Commission anticipates that buildings will be healthier to live and work in as well as more affordable to operate. Proposals will be submitted in the first quarter of 2003 and contracts will be developed in the second quarter of 2003.

Programmatic Solicitation Targeted to Reducing Standby Loss in Equipment

The PIER Buildings team will address opportunities to reduce energy lost during equipment standby modes. The team began investigating this issue in 2002 and identified specific opportunities to mitigate this problem. Upon completion of a scoping exercise to further identify all areas that can be significantly impacted through public interest research, the PIER Buildings program anticipates developing a solicitation in this area and releasing it in the latter half of 2003.

Collaborative Research with the California Commissioning Collaborative

The California Commissioning Collaborative (CCC) is a group of government, utility, and building services professionals who are committed to developing and promoting viable building commissioning practices in California. The CCC facilitates the development of cost-effective programs, tools, techniques, and service delivery infrastructure that enables the implementation of the building commissioning process in new and existing buildings with an ultimate goal of improving building performance. Because of its collaborative nature, focus on market needs, and strategic outlook to addressing commissioning issues, the CCC is a valuable collaborator in ensuring that public interest research and market initiatives are well coordinated. Through the CCC, the PIER Buildings program will explore opportunities to better communicate research results to the marketplace, obtain industry feedback on research needs in this area, provide input to statewide market initiatives, and support coordinated statewide research.

Development of a California Optimized Air Conditioner

In collaboration with the DOE and national equipment manufacturers, this proposed effort will develop an air conditioner that operates efficiently and effectively in California's hot, dry climate conditions. This project will address both residential central air conditioners and commercial packaged units. These machines would be appropriate as stand-alone cooling units in the hot, dry climates typical of much of the southwestern United States. In addition, the machines could be used in conjunction with separate dehumidification systems in humid climates to reduce overall energy use and enhance overall system performance. Preliminary estimates suggest that a hot/dry climate air conditioner (H/D AC) could improve performance during peak demand times (that is, very hot weather) by about 25 percent compared to machines conforming to the most recent standards.

Phase 2 Research

As the PIER Buildings program matures, some early projects are coming to a close and certain technologies are emerging as strong candidates for success with additional incremental public support. For these Phase 2 research candidates, the program is placing a strong emphasis on commercialization potential and participation from industry partners. Unlike more basic research projects where the actual outcomes of the research are not always clear due to the investigative nature of the research, Phase 2 projects must be justified based on a much clearer vision of market potential and participation of market partners to ensure that the research does,

in fact, result in useful market products. Specific areas to be explored for possible Phase 2 research include night ventilation systems; integration of commercial diagnostic tools into appropriate control products; commercial refrigeration; and more efficient heating, ventilating, and cooling systems for portable classroom applications.

INDUSTRIAL/AGRICULTURAL/WATER END-USE ENERGY EFFICIENCY

Industry

California's industrial base is substantial. The availability of reliable and affordable energy for these industries is critical not only for California's economy but for the national economy as well. The major industries—such as food processing, electronics and e-commerce, and petroleum extraction and refining—all depend on continued low-cost and reliable energy. The PIER program staff analyzed the industry issues and energy needs of selected industries by working in collaboration with industry representatives, and identified RD&D options to overcome industries' energy-related problems. In 2002, PIER undertook this effort for food processing and electronics and e-commerce industries, since both are among the five largest industrial electricity users in California. In addition, the operations of both these industries are heavily dependent upon the reliability and quality of electrical energy. The reports on industry issues, priorities, and RD&D options for mitigating the issues was the basis for a request for proposal (RFP) for the food processing industry issued in November 2002. Three short-term projects were also undertaken to meet the immediate concerns in the area of power quality for electronics and food processing industries.

Besides industry-specific projects, the IAW program initiated projects that benefit multiple industries and also assist electric utilities in designing energy-efficiency rebate programs. For example, an RD&D project was initiated for benchmarking the efficiency of compressed air utility systems. This project was conducted in collaboration with the Southern California Edison electric company and the Emerging Technology Coordination Council (ETCC). ETCC is a coordination and technology transfer group comprised of California electric and gas utilities and the PIER program staff.

In September 2002, the State Industries of the Future program of the DOE awarded a contract to the IAW program for developing energy profiles and assessing energy issues, needs, and RD&D plans for petroleum and chemical industries in California. These two industries are the largest energy users in California.

Agriculture

Agriculture constitutes a large and a vital segment of California's economy, export, and employment. Agriculture depends highly upon electrical energy for irrigation and post-harvest processing. Electrical costs and power reliability are critical for successful and sustainable agricultural operations. In 2002, the PIER program continued its RD&D activities in developing techniques for advanced irrigation and other load-management practices to help this sector cope better in the restructured electric market. No new contracts were issued in this area.

Water

The availability of low-cost, clean water is essential to California's economy and continued prosperity. The state depends heavily upon the transportation of a large volume of water across the state. Also important is the treatment of substandard and saline water in large quantities. Both of these activities rely heavily on electricity. The reliability and low cost of electricity are critical requirements for securing potable water and treating wastewater. RD&D activities that help improve the energy efficiency of processing water for urban, industrial and agricultural consumption and an energy-efficient treatment of wastewater recovery continued to be the focus of this program area. PIER entered

into a contract with the American Water Works Association Research Foundation (AWWARF) to undertake a systematic evaluation of the impact of increased electricity costs and disruptions, and for developing an RD&D plan for mitigating the energy costs and reliability issues. This plan will form the basis for seeking RD&D projects that focus on energy-efficient water treatment technologies. The program continued to manage the existing contracts with the consortium of California water utilities and worked with them to transfer the technologies developed through these projects to potential end users.

2002 Progress Update

During 2002, the PIER program's IAW End-Use Energy Efficiency group engaged in two parallel paths for investing in RD&D projects. The first path actively sought industry and stakeholder participation in prioritizing technologies and projects that would be more responsive to industry needs through a programmatic solicitation. Concerned by the uncertainties of electricity supply and the rising costs of electricity in California, the IAW team found a number of willing industrial, agriculture, and water treatment partners. Several industry organizations actively engaged in a dialogue to define the specific needs of the stakeholders. The outcome of this collaborative planning is discussed below. On the second parallel path, the program invested in certain projects that were endorsed prior to the development of plans by the critical industries that were engaged in the dialogue. This ensured that the RD&D projects were responsive to industry needs and priorities in the immediate future.

Following are the specific RD&D projects funded by IAW and related activities in 2002 that took into account the industries' concerns and also the public interests implied in the PIER program.

2002 RD&D Awards

Energy-Efficient Refrigeration and Heating in the Food-Processing Industry

Many food and beverage industries require heating and cooling/refrigeration in their operations. Generally, the gas-fired boilers supply the heat while electrically driven refrigeration systems provide the cooling. The cost of the energy consumed by these devices is a major concern of the industry. Simultaneous production and use of required heating and cooling or chilling is a common occurrence in the industry, and a technology that could efficiently coproduce both would be of significant value.

In March 2002, the PIER program granted a $240,000 contract to the Energy Concepts Company to demonstrate a *Gas-Fired Hot Water Heat Pump Thermosorber* to the food and beverage industries in California. Thermosorber is a gas-fired hot water heat pump that transfers heat from lower temperature to a higher temperature. In effect, Thermosorber cools and heats at the same time, using a fraction of the total energy. The proposed technology approximately doubles energy efficiency by coproducing hot water and chilling (cooling) concurrently. This technology is projected to reduce the consumption of natural gas by 40 percent in the hot water production, and reduce the chilling production cost by as much as 80 percent. The first Thermosorber demonstration unit will be installed at an industrial facility in Modesto, California, in January 2003.

Reducing Electrical Energy Use in Wine Processing

Wine making is a major industry in California and a vital part of its economy. Salts such as tartrates of potassium and calcium occur naturally in grapes at near saturation levels. These salts precipitate in wine during storage and reduce the market appeal of

wines. A tartrate stabilization process is commonly used in the wine industry to reduce the concentration of these salts to an acceptable level to prevent precipitation. Electrically driven cold storage is the commonly used method in the United States for this purpose. The total electrical energy consumption for cold stabilization is estimated at about 70 kilowatt hours per thousand gallons of wine.

A contract was awarded to Winesecrets company to demonstrate a new technology for tartrate stabilization process using electrodialysis. This technology requires less than 20 percent of the electricity used in the conventional cold stabilization process. Adoption of this process will enable the California wine industry to improve wine marketability and quality while reducing its energy usage.

Reducing Energy Cost and Electricity Demand in Data Centers

Development of data centers containing computers and servers for California's Internet-based economy increased in the beginning of this decade and has quickly become an important part of the state's economy. Computers and servers are heavy users of electricity. The rapid expansion of information technology has increased electricity demand and made it necessary to seek energy efficiency in data centers to reduce electrical demand on the grid and lower operating costs. In addition to increased energy demand from data centers, there is often a discrepancy between projected electrical demand by developers and building owners and actual electrical consumption. This leads to inefficient operation because there is a tendency to overstate the electrical load of these facilities and their impact on regional power grids. Outdated cooling practices also lead to inefficient operation.

The PIER program has awarded a $500,000 contract to the Lawrence Berkeley National Laboratory to benchmark and categorize representative samples of data center facilities and develop a road map to define the research needs for energy-efficient data centers. The objective is to achieve a minimum of 30 percent reduction in energy use by data centers.

This project will provide accurate information on the electrical demand of data center facilities within electric utilities' territories. It will also suggest technical options for reducing the consumption of electricity.

RD&D for Energy-Efficient Water and Wastewater Treatment

Treatments for both potable water and wastewater are very energy intensive. The recent energy crisis raised the electric rates of several California water and wastewater utilities and created concern for the availability of electric power. The PIER program initiated a collaboration with the research arm of the water treatment industry. PIER has given a $400,000 contract to the AWWARF to develop a *Water and Wastewater Energy-Efficiency Road Map* to identify and prioritize emerging research options related to energy efficiency, cost, and reliability affecting water and wastewater utilities. After completion of the Water and Wastewater Energy-Efficiency Road Map, the Energy Commission and the AWWARF will jointly fund up to three RD&D projects identified as the highest priorities from the Road Map.

RD&D to Mitigate Electricity Reliability Problems for California's Electronics and E-Commerce Industries

The electronics and e-commerce industries are a critical component of California's economy. The recent electricity crisis and its adverse impacts on power availability, reliability, and cost have severely affected the industries' operations. The PIER

Lawrence Berkeley National Laboratory Energy-Efficient Data Centers

program contracted with the Electricity Power Research Institute (EPRI) to form a working group for the electronics industry, primarily through the Silicon Valley Manufacturer's Group and other high-tech businesses located throughout California. EPRI is developing a technology road map to identify technologies and tools to mitigate the power reliability, availability, and cost issues. The contract entails meeting periodically with the working group to assess energy needs, issues, and priorities. It also involves demonstrating emerging technologies to overcome power quality and reliability problems that adversely affect industrial production and cause heavy economic losses.

Two projects in the area of electrical power quality/reliability and real-time pricing (RTP) signals were funded through this contract. The first project applied a new technology at a semiconductor manufacturing facility to help overcome production interruptions caused by voltage sags. The second project involves demonstrating the ability of several industrial customers to respond to real-time electricity price signals (electricity cost) and make informed decisions about load shedding to reduce system peak loads and lower the electricity cost to the company.

The IAW program also awarded two contracts to the Electric Innovations Institute(E2I)—an EPRI affiliate—for industry-specific technology demonstration projects. These contracts provided California's e-commerce and food processing industries with the tools needed to mitigate power reliability and cost issues. One project involved assessing the vulnerability of a food-processing plant to power quality fluctuations and mitigating such events. The second demonstrated and validated a new technology for a facility with digital loads to overcome electrical harmonics problems and save energy in the process.

Collaboration with the Food Processing Industry for Energy Efficiency

California's food processors are major users of energy and are also a critical part of California's economy. The food processing industry consumes over 5 percent of all the electrical energy used in California. It is also a major user of thermal energy. Electricity is primarily used for refrigeration, freezing, fluid separation, water treatment, electrical motors, and pumps. In 2002, the PIER program continued its contract with the California Institute for Food and Agricultural Research (CIFAR) to form an industry working group to assess energy issues and recommend energy-efficient technology opportunities to mitigate problems created by the recent energy crisis. Based on the Energy Issues and Technology Road Map developed by the industry group, in November 2002 the CIEE issued an RFP for $3 million to solicit RD&D projects. The responses to the RFP are expected in January 2003 and awards expected by June 2003.

Benchmarking Energy Efficiency of Compressed Air Energy Systems

Numerous California industries use compressed air as a major and critical component of manufacturing operations. Although methods are available in the industry to control the efficiency of the compressor unit, no methods are currently available to quantify the compressor central plant efficiency. In some industries, up to 40 percent of energy associated with compressed air systems is wasted. In most plants, there are many opportunities to conserve energy in the generation, distribution, and use of compressed air. In collaboration with California utilities and the Emerging Technology Coordination Council, the PIER IAW program gave an award to Southern California Edison to develop a methodology to quantify compressed air central plant efficiency and to establish procedures for enhancing efficiency of compressed air systems. The project commenced in March 2002 and is expected to be complete by July 2003. Establishing this critical benchmark will help the electrical utilities to fully and accurately gauge the impact of efficiency improvement measures and grant rebates and incentives accordingly.

Energy-Efficient Laboratory Fume Hoods

An existing contract with the LBNL for developing energy-efficient tools for laboratories and clean rooms was augmented to include development of an energy-efficient fume hood. Fume hoods are used in pharmaceutical, chemical, and biotechnology companies for eliminating hazardous fumes at a considerable energy expense. The energy-efficient fume hood that is being developed will reduce the facilities' energy consumption by up to 50 percent as compared to currently available fume hoods.

Electrical Energy Storage Technology RD&D Planning Workshop

In September 2002, the PIER IAW program organized a one-day workshop for planning a joint PIER and DOE storage technology demonstration solicitation. The workshop was conducted in San Francisco and explored the nature and scope of electric energy storage technologies that might be funded by the PIER program. In recent years there have been rapid developments in storage technologies. Electrical storage provides a wide range of benefits such as load leveling, backup power for reliability and interruptions, spinning reserves, frequency control, reserve margins, distribution and transmission stability, creating dispatchability for intermittent renewable resources and power quality. Based on the findings of this workshop and input from the other PIER teams, the PIER program will issue a solicitation for electrical energy storage demonstrations by early 2003. PIER believes that demonstrating these technologies, and their eventual adoption, will enable California customers to overcome the problems associated with sharp electrical demand peaks, power quality, and reliability.

Lawrence Berkeley National Laboratory Energy-Efficient Fume Hood

Storage technologies have applications that cut across several PIER program areas. Consequently, the solicitation is expected to seek solutions that advance the goals of the entire PIER program.

Success Stories

Harmonic Filtration Technology for Data Centers

As the use of computers grows in California industries, the facilities housing these computer electrical loads must overcome the harmonics power quality problems these computer systems generate. The harmonics problem in turn creates additional heating in the electrical system, requires bigger transformers, adds to a facility's air conditioning load, and in general adversely affects the energy efficiency of the facility. Several California companies are seeking solutions to this problem. PIER decided to test a new power quality technology at the California Franchise Tax Board (FTB) to validate the technology's performance and energy savings.

The project was commissioned to conduct laboratory and field measurements of the energy-efficiency improvements provided by a power quality emerging technology that claims to provide substantial energy savings in addition to mitigating the system harmonics. This technology is specifically designed for digital loads and the high third harmonics these digital systems produce. The primary field evaluation location was the FTB Building 1 in Sacramento. FTB Building 1 is approximately 450,000 square feet in size and contains a data center and a large computer processing area with over 2,500 personal computer workstations. This site is representative of California industrial data centers and computer processing centers.

The project was able to validate a 4–6 percent energy saving from installing the new technology. As a result of this performance validation, FTB plans to include this technology in its new proposed building, and the U.S. Army Corps of Engineers may make this technology a standard specification in new facilities design.

Power Quality Mitigation Improvements for the Food-Processing Industry

Increased automation in the food-processing industry makes it quite susceptible to power quality fluctuations. Minor interruptions can cause days of plant shutdowns and large economic losses. Power quality is identified as an issue of concern in the technology RD&D plan developed in collaboration with the industry. This project was initiated and successfully completed to establish a methodology for identifying and reducing power quality problems.

For this demonstration, a food-processing plant in Modesto, California, was used as a representative industrial site. In-line monitoring systems were installed to collect real-time performance data from plant equipment while the food processing was underway. Using this monitoring data, plant process equipment schematics, historical plant process performance data, and overall process sensitivities to different power quality disturbances and their causes were defined. Equipment sensitivity data was compared with other industrial process equipment to determine the level of sensitivity to electrical disturbances and recommended procedures to make the equipment less sensitive. Technical solutions for mitigating the problem were developed for both the food-processing plant and the entire food-processing industry. Based on this work, the food-processing plant has decided to deploy the same techniques at its other company plants and industrial food processors in California; adjoining states have shown interest in implementing this methodology as well. Based on this work, a research organization is proposing industry-wide equipment standards development for the food-processing equipment industry.

Outlook

The PIER IAW program will build on the foundation of industry cooperation and analysis to issue major

A Food-Processing Plant in Modesto Uses PIER-Funded Methodology to Identify and Reduce Power Supply Interruptions and Related Power Quality Problems

solicitations for energy efficiency and reliability RD&D for the electronics and e-commerce industries. In collaboration with the AWWARF, the water and wastewater treatment energy efficiency RD&D plan will be completed by mid-2003 and a solicitation for RD&D projects will be issued.

To provide a sound analytical footing for future RD&D projects, the energy use profile will be developed and energy intensive processes analyzed for the petroleum and chemical industries in California. The program also plans to hold workshops to precisely establish a link between electricity and irrigation. It will also assess the impact on irrigation practices and electricity consumption due to water shortages in California caused by federal water curtailment.

RENEWABLE ENERGY TECHNOLOGIES

2002 Progress Update

Due to the recent passage of SB 1078—the Renewable Portfolio Standard—the following is an expanded discussion of the Renewable Energy Technologies program area within PIER.

The mission of the PIER Renewable Energy Technologies area is to help develop renewable energy that will provide significant public benefits in California's electricity system of tomorrow. Four primary objectives to achieving that mission are to (1) maximize value provided by renewables; (2) lower the cost of energy supplied by renewable resources; (3) expand applications of renewables in California's electricity system; and (4) pursue breakthrough renewable technologies. To date, research work in the PIER Renewables area has been driven by this mission and these objectives. However, passage of a Renewables Portfolio Standard (RPS) in California is influencing the mission and objectives. In particular, all ongoing and proposed work in the area must take into account its role in helping achieve the RPS goals. From this perspective, research work in the area is grouped into the following types:

- Activities that help build a road map for meeting the RPS goals and developing future renewables with high public benefits
- Demonstrations of near- and medium-term renewable technologies that can be deployed as part of an RPS strategy, help increase renewable diversity and affordability, and have wide transferability across California
- Research work that addresses special California needs or opportunities and is highly leveraged by private industry, the federal government, or other stakeholders

Building a Road Map for the RPS and Future Renewables

The RPS will strongly influence renewable energy

development in the state. It sets an aggressive pace and outcome for renewable energy growth in California. Between 2003 and 2017, California's IOUs are required to procure 1 percent per year of their needed electricity supplies from renewable resources. By 2017, 20 percent of the IOU's electricity supplies are to come from renewables. Achieving the RPS 20 percent goal will double the amount of electricity currently provided by renewables in California.

While the RPS sets a renewables growth rate, it does not establish a road map for renewable growth. There are no targets for contributions from specific renewable resources and no prescribed prices for renewable electricity procurements. However, SB 1078 does require the California Public Utilities Commission (CPUC) to establish a process that will develop renewables based on a "least-cost, best-fit" approach.

Achieving the RPS goals on a least-cost, best-fit approach will be challenging. While California has a rich supply of renewable resources, much of the less expensive and easier- to-harness renewables have already been developed. For example, California's wind resources are estimated to be capable of providing in excess of 7,000 MW of installed generating capacity. Yet, less than 2,500 MW of California's wind resources are located sufficiently close to transmission lines or have wind speeds capable of being economically developed using commercially available wind energy systems. Approximately 1,700 MW or over two-thirds of California's better wind resources have already been developed. The remaining one-third of the better wind resources are located in less accessible areas or are far from transmission lines. Aside from repowering activities at present wind parks, future wind development in California will mean tapping into the estimated 4,500 MW of lower wind speed resources. Harnessing these lower wind speed resources will require higher levels of sustained subsidies (if conventional wind energy systems are used) or deployment of new wind turbines capable of generating electricity at competitive prices in the lower wind speed regions. In addition, developing these wind resources in accordance with a best-fit approach requires accurate information on the quality of the wind resource and its proximity to transmission lines and other electricity system resources. Until very recently, existing wind resource information has been limited to wind mapping activities conducted over 15 years ago. While representing excellent information for its time, the 1980s wind maps provide little help in identifying how best to develop the lower wind speed resources to achieve the current RPS goals and provide high levels of benefits.

Similar situations face development of California's remaining biomass, solar, geothermal, and water resources. Each resource underwent rapid development in the 1980s, followed by slower growth and, in some instances, declines by the mid-1990s. While there are a number of reasons for the slowed growth in renewable energy development, it's clear that the renewables left untapped involve greater economic, technical, or environmental challenges. In essence, the gold rush of renewable energy development in the 1980s resulted in the collection of the more visible and easily gathered "renewable nuggets." California's remaining renewable resources will be more difficult to mine. Moreover, California's current renewable development landscape is also significantly different and more complex than that facing renewable energy development in the 1980s. Twenty years ago California needed baseload capacity, which could be supplied by central station renewable energy power plants. California's present electricity system faces mostly a shortage of peak generating capacity with some localized baseload growth demands. Similarly, two decades ago California still had excess transmission capacity. Today, California's grid is characterized by severe constraints in transmission

capacity and a bevy of congestion problems. Effective development and deployment of renewables that both meet the RPS goals and provide significant public benefits will require a well-conceived road map. In 2001, the PIER Renewables area initiated several different activities to help create a road map for renewable energy development and deployment in California. Among the products being developed are the following:

- Up-to-date and higher resolution resource assessments as needed to better identify the quality and locations of California's remaining renewable resources
- Technology characterizations providing status and trends of renewable energy technology costs and performance
- Web-based tools that enable prospective users of renewable energy technologies to determine the feasibility of employing different types of technologies
- A strategic value analysis that identifies potential electricity system "hot spots" in the future, the types and magnitude of renewable resources that could possibly be used to address the "hot spots," and comparisons between conventional versus renewable energy solutions

Three renewable resource assessment studies were undertaken during 2002. A high-resolution wind resource assessment has recently been completed that provides wind speed and power across the state at a 200-meter grid size and at various hub heights. In addition, a technology and resource assessment on ocean wave energy along California's coast was initiated and is to be completed by early 2003. Lastly, an assessment of biomass resources across the state was initiated as part of the California Biomass Energy Consortium; it is due to be completed by late 2003.

Resource assessments provide information on the quality and location of California's renewable resources, but provide no information on how to harness the resources. Technology characterizations that provide accurate performance and cost data on renewable technologies are needed to assess effective ways to harness the renewable resources. The PIER Renewables area has obtained up-to-date renewable technology characterizations developed by the Electric Power Research Institute (EPRI). As part of its 2002 membership, the PIER Renewables area was provided with EPRI's Renewable Energy Technical Assessment Guide (TAG-RE), which will be used to develop a technology guide specific to renewables in California.

Several different web-based evaluation tools were under development during 2002, including a building-integrated photovoltaic (BIPV) evaluation tool. BIPV products can act as a roofing material as well as a means of meeting peak electricity demands at the building. The BIPV evaluation tool allows building owners to compare the costs and benefits of using BIPV against the cost of using conventional roofing materials and energy efficiency measures when considering a new roof. The BIPV tool will be available free of charge via the Energy Commission website. These tools are very valuable considering successful inroads being made in BIPV technologies under the Sacramento Municipal Utility District (SMUD) programmatic contract (discussed in depth later in this section). Four BIPV projects are pushing the envelope toward roof integration of PV modules in the marketplace. UNI-SOLAR has demonstrated a batten and seam product that covers the entire roof of a historic building in Mendocino. Astropower is producing a module that integrates with concrete tile roof. Schott Applied Power has a penetrationless flat roof mounting solution. In addition, PowerLight is reinventing its flagship PowerGuard product for residential purposes.

The strategic value analysis was originally developed to help identify the appropriate types and best locations for developing and deploying renewables to meet California's electricity needs. However, the study also represents a means to

evaluate the impacts and benefits of deploying renewables to meet the RPS goals. The study has four major components. First, power flow simulations are conducted of California's electricity system over the next 20 years to identify possible capacity, congestion, or reliability problems. The simulations are based on information obtained from the IOUs, the Western States Coordinating Council, and California municipal utilities, and take into account different load growths, climate variations, hydroelectric supplies, and contingency occurrences to provide a bracketed set of electricity scenarios. Areas of the state that have significant capacity, reliability or congestion problems are identified as potential "hot spots." Second, information on the locations and characteristics of the hot spots are transferred into a geographical information system (GIS) database. Renewable resource information, climate zones, environmental information, and certain types of demographic information are also transferred into the GIS database. Overlays are developed that examine the quantities and types of renewables contained in the identified hot spot areas. The power flow simulations are then run again, using various penetration levels of renewables to determine their ability to help resolve the hot spot conditions. The preliminary results indicate both the upper and lower limits at which renewables could possibly help address the hot spots. While the preliminary results indicate the possible impact of renewables, they do not compare how renewables compete against other solutions, such as transmission and distribution upgrades or fossil generation options. Consequently, a third component of the study is to conduct comparisons between renewable and other solutions based on performance and cost. Results from the combination of the penetration analyses and the performance/cost comparisons will give an indication of the feasibility of deploying renewables to help address the hot spots. However, the performance and cost comparisons also can be used to back into a set of technical and cost targets for future renewables. In particular, where commercially available renewable technologies cannot compete on a cost or performance basis against existing conventional solutions, the derived targets can act as research and development targets for future renewable technologies. The fourth component of the study is to evaluate the ability of distributed generation renewables to help address localized electricity system problems as well as examine how localized solutions can affect regional electricity issues. Case studies will be conducted in at least three locations of the state to examine the renewable distributed generation options.

Currently, data sets for the power flow analyses have been collected from the three IOUs. Over 6,000 power flow runs have been conducted and very preliminary results obtained for the Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDG&E) service territories. A significant amount of renewable resource information and other critical environmental, climate- zone, and demographic information has been collected for use in the GIS. The study is being coordinated with transmission planners from other offices within the Energy Commission as well as with staff from the California Independent System Operator (CAISO) and the CPUC. Preliminary results for the strategic value analysis are due in early 2003, and the final study is due by mid-2003. Results from the study will be provided to the CPUC in mid-2003 for use in the transmission study required under the RPS.

Demonstrations of Near- and Medium-Term Deployment of Renewables

The PIER Renewables area has pursued development of renewable technologies for deployment in the near and medium term on two fronts.The first front focuses on developing projects that address affordability and diversity issues facing California's electricity suppliers. These "programmatic" projects are intended to act as templates that can be widely adopted by other

California electricity suppliers. The second front focuses on improvements in specific renewable resources to increase their near-term value to California's electricity system.

Over $31 million has been provided under the PIER Renewables area for three programmatic efforts: $13.6 million to SMUD; $11.7 million to Commonwealth Energy; and $5.8 million to Hetch Hetchy Water and Power (originally awarded to Northern California Power Agency).

Renewables in Hot Inland Regions: (SMUD). Like other electricity suppliers whose service territory is located in the hot inland regions of California, SMUD faces intense "needle peak" demand, driven primarily by air conditioning loads during high summer temperatures. In addition, like a number of municipal utilities, SMUD has traditionally purchased a significant amount of its electricity from outside the district, leaving it vulnerable to volatile market conditions. The challenge to electricity suppliers facing high summer peak is using the same solar resource creating the peak demand problem to help cost-effectively resolve it. Nineteen projects make up the SMUD programmatic effort. Fourteen of the projects involve lowering the cost of solar technologies or using solar technologies in ways that more effectively address peak demands. The remaining five projects look at ways to lower the costs of wind and biomass technologies, thereby increasing the diversity of energy supplies in the region and helping reduce the need to import electricity.

The hot inland renewable template effort has just completed its first year of operation and has shown significant progress. All 19 projects have signed subcontracts, held kickoff meetings, and are proceeding with research and development activities (except for the Oakridge National Laboratories Hybrid Lighting demonstration project, scheduled for installation in 2004). Some projects will finish in early 2003, while others, such as the Utility System Capacity and Customer Demand Value of PV project by National Renewable Energy Laboratory (NREL) area already completed. Of the 14 solar projects, nine are well into the development of prototype systems, and three have completed early prototype technologies that could substantially lower the costs of photovoltaic systems.

One such example is UNI-SOLAR, which has developed a low-cost and dual function (roof and PV system) prototype. The laminate and batten PV system is delivered as a roll of material that is easy to install and can be applied as the roofing material on any new or existing roof underlay. Comprised of triple-junction, thin film, amorphous PV cells, the UNI-SOLAR product has the capability for low-cost manufacturing.

Another completed prototype involves a unique flat roof mounting system developed by Schott Applied Power Corporation. One of the major hurdles facing the use of PV systems on flat roofs involves roof penetrations that occur when fastening the PV system onto the roof. Roof penetrations represent a potential for water damage from leaks. Consequently, most PV systems for flat roofs typically use expensive means to avoid leakage from roof penetrations. The prototype developed by Schott uses a flat roof mounting approach that eliminates roof penetrations but stays safely secured even in very high wind conditions.

Extensive review of the programmatic goals and status of the projects from industry experts ensures that the projects are proceeding in a positive and meaningful direction. Two Renewable Programmatic Advisory Committee and two Critical Project Review meetings were held with favorable results. An annual review of the SMUD programmatic program received a positive recommendation to proceed from the Energy Commission's Research and Development Committee.

Public and private web-based information on the SMUD programmatic program and each of the individual projects is available at www.smud.org/pier.

Turning Environmental Liabilities into Small-Scale Renewables: (Commonwealth). California's Chino Basin is located approximately 40 miles east of Los Angeles and straddles the west ends of San Bernardino and Riverside counties. Like most of southern California, the region encounters hot summers reflective of its abundant supply of sunshine. The basin also faces significant environmental issues. It is located in the South Coast Air Quality Management District, which represents an area of 12,000 square miles and a population of over 14 million people. Due to the dense population, high volume of vehicle traffic, and large number of businesses, air quality in the district is among the worst in the country. Although the air district has taken a number of steps to help improve air quality in the region, it typically violates federal health standards for ozone 120 days out of the year.

Ground water quality is also a concern in the Chino Basin, which has one of the highest concentrations of dairies in the world. Home to over 300 dairies, nearly 350,000 cows are located within a 50-square-mile area known as the Chino Basin Dairy Preserve. The high concentration of cows poses special water quality considerations as the dairies generate over 770,000 tons per year of animal manure that has historically been stored on agricultural lands. Runoff from improperly stockpiled animal manure threatens to contaminate both surface and ground-water supplies.

Electricity service in the Chino Basin is provided by the transmission and distribution system of Southern California Edison (SCE). Transmission studies conducted by the CAISO have identified possible problems with voltage stability in the SCE region by 2005, depending on growth in the region, new generation supplies, and upgrades to current transmission lines. However, the Chino Basin is one of the fastest growing areas in the state and new generation within the basin will be critical to ensuring adequate power delivery.

In many rapidly growing areas in the state, potential deterioration of air and groundwater quality from continued growth pose concerns to the affected communities. Similar worries revolve around the impact of additional population on electricity demand and, in turn, environmental impacts from new generation facilities. The template being established by the Commonwealth Energy programmatic effort is one wherein the appropriate use of renewables helps convert an environmental liability into a clean electricity solution. In particular, the template is based on a combination of biomass and solar resources to form distributed generation options. Six projects make up the template. Three of the projects focus on lowering costs or improving performance of biogas systems, including landfill gas-to-electricity operations, dairy biogas systems, and wastewater treatment to electricity systems. Two of the projects involve developing BIPV systems that can help meet peak demand on commercial buildings. The sixth project looks at ways to use the developed biogas and BIPV technologies as distributed generation options in a "mini-grid" setting. The study will provide conclusions on the impacts and benefits of the renewable distributed generation approach in deferring transmission and distribution upgrades as well as benefits to businesses employing the renewable systems as self-generation options.

Initiated in late 2001, two of the six projects in the Commonwealth template have completed early products. Resource mapping of biogas and solar resources have been conducted for the distributed generation project as well as the first set of power flow runs on the mini-grid selected as being

representative for the region. The full set of analyses and conclusions are expected by early 2003. Similarly, scoping studies and preliminary economic analyses have been completed on the commercial BIPV project.

Integrating Renewables to Meet Congestion and Capacity Problems in Urban Areas (Hetch Hetchy). San Francisco, "the City by the Bay" and one of the most urbanized and congested cities in California, is vulnerable to disruptions at any given time. Because of the given location of the city, which is at the end of a peninsula, there is a limited ability to import electricity into San Francisco. All the power coming into the city follows through overhead and underground transmission lines along a single pathway from an electric substation near the city of San Mateo to another substation in Daly City. During periods of peak demand, the city can import over existing transmission lines only about 60 percent of the power needed to meet its needs. In December 1998, this infrastructure was disrupted, resulting in an economically damaging daylong blackout for parts of the city. Therefore, San Francisco is dependent on the operation of power plants located in the city. Currently, power plants are located at just two sites: Hunter's Point and Potrero, both in southeast San Francisco. The plants located at these sites are old, inefficient, prone to breaking down, and many times more polluting than new power plants.

For years, communities in southeast San Francisco, where there is a high level of respiratory disease, have been calling for the shutdown of the Hunter's Point plant. In 1999, PG&E and the mayor signed an agreement to close the plant as soon as reliable replacement power was available. And in 1999, a victim of California's electricity deregulation experiment, PG&E sold its Potrero Plant to out-of-state merchant company, Mirant. Mirant decided to expand the facility by adding a new power plant more than twice the size of the existing plant. That proposal has met with strong resistance and has raised further alarm about environmental justice in neighborhoods bordering fossil fuel plants.

The city's Board of Supervisors responded to this situation in May 2001 by unanimously passing an ordinance, "Human Health and Environmental Protection of New Electric Generation." The ordinance directs the San Francisco Public Utilities Commission (SFPUC) and the Department of the Environment to prepare an energy resource plan that considers all practical transmission, conservation, efficiency, and renewables alternatives to fossil fuel electricity generation in the city and county of San Francisco. The city now has an energy resource plan with set priorities to maximize energy efficiency, develop renewable power, assure reliable power, support affordable electric bills, improve air quality, prevent other environmental impacts, support environmental justice, promote opportunities for economic development, and increase local control over energy resources. The city's energy plan includes the development of renewable power. This became evident when in 2002 San Franciscans voted overwhelmingly for Proposition B, which authorized $100 million in bonds to finance renewable and efficiency projects in city facilities. In addition, proposition H was also passed, giving the Board of Supervisors the power to issue revenue bonds for renewable and efficiency projects in the private sector. The city's specific objectives for renewables are 7 MW by 2004; 28 MW by 2008; and 50 MW by 2012.

The template being established by this programmatic renewable project has 10 linked renewable energy projects that will help accelerate the implementation of San Francisco's energy plan. In particular, Hetch Hetchy/SFPUC is providing a coherent framework for assessing the city's opportunities to overcome its electric infrastructure vulnerabilities and assure reliable, affordable, and

sustainable sources of electricity. Hetch Hetchy/SFPUC together with Public Renewables Partnership (PRP) will work through a collective planning process to investigate the feasibility and benefits to California's power system from a comprehensive resource-based generation portfolio that includes a significant proportion of renewable energy. To help resolve the transmission constraints of the city, a study on investigating the feasibility of interconnecting Pacific high voltage direct current (HVDC) Intertie is being done. A pre-feasibility assessment of DC and AC transmission options into California from potential sources of renewable energy has already been submitted to the Energy Commission for review and comments.

Two other projects that will help assess and target new renewable energy development are new wind site identification and qualification, and new geothermal resource assessment. A particular project that will help increase affordability of existing renewable energy facilities in this template is upgrading existing geothermal sites. The two renewable projects that will expand affordability and diversity using renewable distributed generation are a distributed generation assessment and a biomass project distributed generation value analysis. Three of the projects in this template that will help developing renewable energy technologies for tomorrow's electricity system are solar thermal parabolic trough power plant assessment, demonstration of hybrid biofuel/natural gas, and assessment of energy storage for renewable generation. In this template, these programmatic renewable projects are expected to develop long-range renewable power procurement strategies that can compete head-to-head on value with traditional utility power resources. The Center for Resource Solution (CRS), together with PRP, will integrate program findings of this template to ensure broad replicability of these projects in California and other neighboring states. In addition, CRS and PRP will be instrumental in achieving their goals through a combination of management and technical activities and ensuring the availability of cost-effective renewable energy supply in both the near- and long-term solutions.

Specific dates for the Renewable Programmatic Advisory Committee (RPAC) meetings and Critical Project Review (CPR) meetings were identified. A project tracking system and other administrative protocols were initiated and established. Match funding requirements with the prime contractor and subcontractors were all secured and documented. SFPUC is continuing detailed negotiation with each technical subcontractor. Executed copies of all subcontracts are expected to be provided to the Energy Commission in early 2003. Public and private web-based project information has been established and is now available at: http://www.resource-solutions.org/PIER/PIERindex.htm.

The programmatic efforts involve groups of projects used to address issues of electricity affordability and diversity facing California's electricity suppliers. However, PIER Renewables also has focused research efforts in specific renewable areas to improve near- and medium-term value of renewable resources in California's electricity system. The following provides an update on the progress made as of 2002 in each of the renewable technology areas.

Wind Energy Progress

California has tremendous wind resources with a potential generation capacity estimated to be as high as 25,000 MW. To date, the state has approximately 1,700 MW of installed wind capacity. Wind generation capacity grew steadily from around 600 MW in 1985 to approximately 1,500 MW by 1995. However, wind development since 1995 has been slow. Only 200 MW of wind capacity was installed between 1995 and 2001. Loss of relatively lucrative standard offer contracts, lack of nearby

transmission capacity, and concerns over avian mortality and aesthetics have all played a role in slowing the growth of wind energy in California. To help with future wind development, work in the PIER Renewables area has focused on the following activities.

Identifying California's Wind Resources. Until recently, the only statewide assessment of California's wind energy resources has been the 1985 California Wind Energy Atlas, over 15 years old. The industry move to taller wind turbines combined with a need to have a wind-mapping tool capable of assessing wind resources in a variety of locations and conditions severely limited the usefulness of the older wind resource assessment. PIER Renewables contracted the development of a high-resolution wind resource assessment for California, which was released in December 2002.

Lowering the Cost of Wind Energy in California. Assessments show that California has tremendous wind energy resources. However, a significant amount of the state's wind resources have not been tapped for energy production. One of the barriers to further wind energy development is its cost. At electricity generation costs of less than $0.04/kilowatt-hour (kWh), wind energy is one of the least expensive forms of alternative electricity. However, technological advances in combined cycle technologies and low costs of natural gas have lowered wholesale electricity prices to below $0.03/kWh. Because wind energy is intermittent, it cannot bid for the more lucrative ancillary service agreements. Consequently, wind electricity generation costs must be reduced if wind energy is to become more competitive in unsubsidized markets. Similarly, because wind energy has no fuel costs, the only ways to reduce the electricity generation costs are to increase capacity factor or decrease capital costs. In 1998, the Energy Commission, in conjunction with NREL and the Wind Turbine Company (WTC), initiated development of a new-generation wind turbine. The project focused on reducing the amount of material needed in the turbine while increasing its ability to operate reliably in a wide range of wind conditions. Due to the reduced materials, which lower capital investment, WTC systems are projected to lower electricity generation costs in the near term to below $0.035/kWh and in the longer term to $0.025/kWh. A 250 kW prototype turbine was designed, fabricated and tested at the National Wind Technology Center in Colorado. The successfulness of the prototype tests resulted in a decision among the partners in 2001 to proceed with development of a 500 kW commercial-scale prototype. The unit has been designed, built, and installed in Lancaster, California. Currently collecting operating hours, the WTC system has received international attention as one of the leading edge efforts to lower wind energy costs. In addition, WTC is currently examining investment opportunities to begin moving the technology into the marketplace.

In 2001, the PIER Renewables area also funded an effort by Clipper Wind under the SMUD programmatic contract to help reduce wind energy costs. Clipper Wind is developing a distributed drive gearbox for use on wind turbines. As wind turbines have increased in size, gearbox torque loads and component costs have increased accordingly. Clipper Wind's distributed generation drive train uses multiple smaller and parallel gearboxes to reduce the torque seen by any single gearbox. This approach not only increases the overall reliability of the wind turbine, but also helps to reduce overall weight and therefore costs. The focus of the project is to design, construct, and test a commercial-scale (1.5 MW) distributed generator drivetrain (DGD) along with an integrated controller. The preliminary design has been finalized and a bill of materials has been sent to gear and gearbox manufacturers, machine shops, and foundries. Preparations are being made for assembly and testing at NREL, planned for early 2003.

Solar Energy Progress

Solar energy represents the single largest renewable resource in California. The state is literally drenched in sunlight that could provide a tremendous amount of electricity if developed cost-effectively. Theoretically, solar energy could provide a gargantuan 40 million MW of installed generating capacity if the entire state were covered with photovoltaic systems having 10 percent conversion efficiencies. While the concept of covering the entire state with solar panels is unrealistic, it demonstrates the magnitude of California's solar resources. Given such magnitude, it is difficult for many people to understand how solar energy resources can currently provide less than 400 MW of California's installed capacity. However, solar energy is an intermittent resource with presently high capital costs. Developing significantly more electricity capacity from California's solar resources requires that solar electricity be more affordable and provide high value to the state's electricity system. Most solar electricity development activities today are based on photovoltaic (PV) or concentrating solar power (CSP) efforts.

Photovoltaic Development. Efforts to develop PV systems in the 1980s were directed toward deploying PV as large central station facilities. This approach assumed central station PV systems offered economies of scale that would prove favorable as the cost of PV materials decreased. However, research projects of utility-scale PV systems showed the cost of the infrastructure (i.e., the land, buildings, fencing, etc.) stayed sufficiently high to prohibit the large central station approach. The emergence of small-scale PV systems for use on commercial and residential buildings demonstrated much better economics. More recently, the concept of building integrated PV (BIPV) systems has become more attractive to consumers due to the advantages of the PV system acting as an integral part of the building roof. For these reasons, PIER Renewables has focused PV-related research on small-scale and BIPV systems for California's architecture.

There is an estimated 50 MW of small-scale PV currently installed in California. The growth potential for PV applied to new homes is large. For example, if 2 percent of new homes built in California had PV systems (at 500 square feet of roof area per house), the first year of new home development would provide a PV capacity of approximately 10 MW. Assuming BIPV systems installed in new homes then grew at a steady rate of 38 percent each year for 20 years, an accumulative BIPV capacity of over 6,000 MW would result. Residential retrofit, parking shade structures, and commercial buildings add additional market potential to PV in California, and could raise the installed PV capacity to as high as 28,000 MW or more over a 20-year period. While seemingly high, a BIPV growth rate of 38 percent may be realistic. The PV industry has shown a consistent 18 percent growth rate per year for the last 20 years, and more recently, has shown sustainable growth at 38 percent per year internationally.

PV must be more affordable and provide high value to the state's electricity system to help achieve high growth rates. The manner in which PV systems are deployed in the state will help determine their value to the electricity system. Like many of today's distributed generation technologies, PV systems are dependent on net metering and interconnection standards to provide Californians with the highest value of their on-site generated energy. This also means that PV systems must be fully integrated into the market as complete systems solutions. Consequently, PIER Renewable research efforts in the PV area are closely integrated with other non-PIER activities to ensure the developed products are market connected and represent complete system solutions. For example, PIER Renewables is working with others toward standards development that will provide optimal installation by qualified

installers of pre-packaged BIPV systems. The specific focus of PIER Renewable PV research activities is as follows:

- **Increasing Value of PV to California's Electricity System.** Small-scale PV (and BIPV generated electricity in particular), has the potential to provide enormous benefits to California ratepayers and electricity suppliers. PV systems provide individual ratepayers with the means to exert control over their electricity options, add stability to their electricity costs, and make meaningful contributions to a cleaner environment. In 2002, 7.2 MW from 2,160 systems were installed, with another 8.5 MW in 1,567 systems awaiting installation utilizing the Energy Commission's Emerging Renewables Buy-down program. When designed and implemented as part of an overall energy efficiency strategy, PV systems can allow consumers to completely offset the need to purchase expensive grid-generated peak electricity. In aggregate, PV systems can help alleviate the need to expand or add new transmission and distribution lines, increase system reliability, and diversify electricity supplies. Some of these benefits can be realized immediately. For example, PIER-sponsored research shows that each kilowatt of customer-owned PV in the SMUD service territory provides $1,100 of value to SMUD (regardless of who owns the system). In the longer term, benefits from PV will play an increasingly important role to California's ratepayers and electricity suppliers.
- **Making PV More Affordable.** The major barriers facing further deployment of small-scale PV systems in California are capital costs of the systems and the costs associated with installation. Today, roof-based PV systems in California in the 100-watt to 1 MW size range are being installed at costs of $6–$9 per watt. These systems produce electricity at a cost of $.18–$.25/kWh (not taking into account any state or federal incentives). If the cost of BIPV systems attains a targeted cost of $3 per installed watt, they will produce electricity at prices approaching $.10/kWh. At this electricity production cost, BIPV competes favorably with other options for supplying peak daytime demand in California. To help achieve this electricity generation cost, PIER Renewables PV research activities largely focus on reducing the cost of PV to $3.50 (unsubsidized) by the year 2005. As such, the PIER Renewables PV research provides a good complement to the PV incentives used in the Emerging Renewables program at the Energy Commission. Specific projects that are accomplishing these system cost goals include four BIPV projects that are ready for market entry. UNI-SOLAR, Astropower, Schott Applied Power, and PowerLight are reducing the balance of system costs, while providing products that are more effective with new construction and retrofit markets.
- **Integrating PV into California's Electricity System.** PIER Renewable efforts to help reduce capital costs of PV systems involve lowering costs of components, systems, and project execution (design, engineering, and installation). Previous component work had concentrated on PV modules and inverters, which represent approximately 55 percent of the total system cost. Systems research involves integrating components in a cost-effective and efficient manner to satisfy market requirements. Industry efforts indicated that a BIPV approach during new construction may be the best way to achieve cost reductions in the systems area. PIER Renewables research is taking a leading-edge position in this area with projects focused on new materials and installation methods that reduce the deployment, labor, and balance of systems costs of BIPV systems. Thus, PIER is concentrating on the 45 percent of installation costs that have the highest potential for reduction in California. In addition, some of the projects include ways BIPV can be installed to provide shade and insulation, thereby generating multiple benefits from the BIPV system. These projects are being funded under the

SMUD and Commonwealth programmatic contracts as previously discussed. Endecon, funded under the Commonwealth programmatic contract, is developing system performance standards that will eliminate the confusion from the variety of separate module and inverter ratings currently seen by PV buyers. Such standards will increase consumer confidence about the performance they can expect from installed systems and help ensure more accurate expectations of PV benefits to the grid.

- **Funding Web-based Analysis of PV Value with Clean Power Estimator**. Clean Power Estimator is an "economics of PV" software freely available on the Internet. It is being funded by PIER Renewables to quantify additional benefits from shading and insulation, for those users interested in these values.

CSP Development. Concentrating solar power (CSP) suffers a similar history to other renewables, with not much development occurring since the 1980s. Currently, 350 MW of CSP is operating in southern California. As demonstrated by the LUZ parabolic trough facilities in southern California, CSP plants with cost-effective storage or natural gas hybridization can help deliver power to the grid when most needed, and not just when the sun is shining. Newer CSP technologies incorporating advanced storage capabilities have the same dispatchability without use of fossil fuels and with zero emissions. The peaking capacity of these facilities can approach 100 percent. However, cost of producing power from CSP facilities ranges from $0.15–0.25/kWh, making cost competitiveness a primary issue for future CSP development. Federal CSP research activities are attempting to lower this cost through technology refinements and economies-of-scale cost reductions.

Future development of CSP in California will be driven by market conditions in the near term, but may be driven by more strategic energy concerns in the long term. The greatest value of CSP systems may come from on-site generation, and use of the waste heat to run absorption chillers or to desalinate water. Many facilities in the Central Valley and California's desert could benefit from CSP systems. To date, CSP facilities that provide this type of combined service do not exist. In addition, small-scale CSP is limited by lack of off-the-shelf technologies with proven track records. Large-scale CSP is limited by the distances between locations of intense solar resource relative to the electricity consumers. In particular, expensive transmission lines are needed to bring large wholesale CSP to population densities requiring the power. In general, PIER Renewable activities in the CSP area have focused on coordinating with DOE to help reduce costs of large-scale CSP and on developing smaller-scale CSP approaches that can provide value to California's ratepayers. Specific research activities are as follows:

- **Teaming with DOE and Duke Solar for Lower-Cost CSP.** In cooperation with DOE, PIER Renewables funded a CSP project under the Hetch Hetchy programmatic contract with Duke Solar. The project involves pre-feasibility evaluation of advanced and lower-cost solar thermal power plants that will lead to an aggregated power purchase agreement (PPA) from a group of California municipal utility companies. The goal is to develop a series of CSP plants consisting of advanced parabolic trough solar thermal power facilities in California totaling 1,000 MW, with emphasis on supply to the Pacific HVDC intertie. The future plants would be built in time-sequenced phases, each consisting of a single plant or complex of plants from 50 to 200 MW in size. A key objective of this evaluation will be to determine the optimum approach for development.
- **Developing Small-Scale CSP Options.** SAIC is developing a 20–25 kW solar dish/Stirling system and designing a solar dish/PV system. If economical, a demonstration of the solar dish/

Stirling system will be installed in SMUD's service territory. This demonstration is attempting to prove performance and reliability so that distributed dishes can be built in California's solar intense regions. PIER Renewables is also funding the advancement of science in concentration technologies that hopes to significantly improve the practicability of reflective optics. This project is using a lens-like reflective concentrator concept and adapting it for uniform illumination of PV cells at moderate sunlight concentrations. The project includes the development and testing of a novel concentrating PV prototype module with increased efficiency and reduced cost and operation. PIER Renewables is also funding development of a novel slat-array concentrator. Similar arrays are being used in Europe to reduce the cost of parabolic CSP systems by 50 percent. PIER is funding a new concept, similar to freznel lenses, that uses slats of highly reflective materials, in a proof of concept/prototype development project. This project has high potential for lower-cost electricity from CSP, or concentrator PV generated electricity. Waste heat would be available for absorption, chiller air conditioning, or desalination. These two CSP projects are being administered under the SMUD programmatic project.

Biomass Energy Progress

Biomass residues represent materials such as agricultural wastes, remnants from lumber mills and wood processing plants, forest thinnings, urban yard and wood wastes, livestock manure, and sewage sludge. Over 60 million dry tons of biomass residues are generated each year in California. If every bit of biomass residue could be used to make electricity, it would provide in excess of 5,500 MW of generating capacity. Due to economic, technical, and environmental constraints, less than 10 percent of California's biomass residues currently provide around 900 MW of generating capacity. Approximately 700 MW of California's biomass capacity is currently provided by 39 power plants using direct combustion processes. The remaining 200 MW are furnished by electricity generated at landfills and wastewater treatment facilities.

As indicated, obtaining 5,500 MW of generating capacity from the state's biomass residues is unlikely for a number of economic, technical, and environmental constraints. Setting aside economic and environmental constraints, thermochemical routes could provide a biomass-generating capacity ranging from 2,000 to 3,000 MW. Similarly, converting residues via biological processes at landfills, wastewater treatment plants, and food-processing facilities could represent an additional 1,000 MW of capacity. However, certain challenges are involved in converting significantly more of California's biomass residues into electricity that provides high value to the grid. Among these challenges are the relatively high costs of biomass-to-energy technologies, inability of these facilities to provide power other than at baseload capacity, and problems in providing anticipated environmental benefits. To help with further development of California's biomass energy resources, PIER Renewables has focused on the following activities.

Improving Economics of Biomass Power Plants. Costs of electricity generation from biomass facilities employing thermochemical processes range from $0.08–0.12/kWh, making it difficult for these facilities to compete against less expensive natural gas-fueled combined cycle plants. Fuel costs can be a significant component in the overall electricity costs. For example, each $10 per ton of fuel costs adds approximately $0.01/kWh to the electricity generation cost. Analyses of 20 years of biomass fuel costs in California show fuel costs went as high as $60 per ton during the mid-1990s. During this period, 66 biomass power plants in the state competed for clean, properly sized, dry biomass residues. However, lumber mill residues represent the only in-state supply of clean, sized, dry biomass

fuels. Because California generates less than six million dry tons of lumber mill wastes annually, this fuel supply can only accommodate approximately 900 MW of biomass power plants. As additional biomass power plants are constructed there will be an increasing demand for the limited quantity of the higher quality residues, and fuel costs will skyrocket, decreasing the cost competitiveness of biomass power plants. Essentially, this is what happened to biomass fuel prices in the mid-1990s. One way to help control biomass fuel prices is to expand the supply base and target use of lower-cost residues. However, most of the lower-cost biomass residues represent relatively low-quality fuels that cannot be easily used in biomass power plants. In 2001, GE Energy and Environmental Research Corporation (GE/EER) began investigating development of an innovative thermal gasification system that could be incorporated into direct combustion facilities and enable use of low-quality residues. In addition, the GE/EER approach would reduce NOx emissions from the facilities by up to 60 percent. GE/EER completed preliminary designs and pilot-scale tests in 2002.

Providing Peak Generation Abilities to Biomass Power Plants. Typically, biomass power plants using direct combustion or gasification conversion routes are large central station facilities. For example, California's 39 direct combustion facilities average around 20 MW in capacity, and a single facility typically consumes over 100,000 dry tons of biomass residues yearly. Due to their size and the nature of direct combustion of solid fuels, these facilities are designed to provide baseload capacity to the grid. In particular, these facilities were not designed to respond quickly to load changes and as such cannot easily respond to demands to provide additional power during peak demand. Consequently, in an electricity system lacking peak generation capacity, these facilities have a limited amount of value. From a financial perspective, the facilities see this limited value in an inability to obtain the higher revenues associated with providing ancillary services to the electricity system. PIER Renewables awarded a contract to the Gas Research Institute (GRI) to equip and test two biomass power plants with low-NOx, natural gas cofiring systems. Results from the demonstrations showed natural gas cofiring improved the overall performance of biomass power plants by allowing better control of the moisture content of biomass residues entering the boiler. In addition, natural gas cofiring enables biomass power plants to provide a limited (up to 10 percent of the plant rating) amount of peaking power to the grid. GRI is currently marketing the low-NOx cofiring systems for application in California. If deployed on all California biomass power plants, it would provide an additional 90 MW of clean, affordable, and renewable peaking capacity.

Expanding Use of California's Landfill Gas-to-Energy Potential. California has over 300 active landfills that currently generate methane-rich gases as part of the normal decomposition process. Landfill gas-to-electricity (LFGTE) systems can be used to capture and convert the methane gases to electricity. However, LFGTE systems are used on less than 20 percent of the state's landfills. One reason for the slow deployment of LFGTE systems in California is the protracted length of time required to obtain a return on LFGTE systems. As designed and operated, methane gases from typical LFGTE systems are generated over 30 years. As revenues from electricity production are tied directly to the amount of methane generated, the slow decomposition draws out the return on investment. Earlier research funded by the Energy Commission and conducted at Yolo County showed that treating landfills as bioreactors could accelerate the decomposition process. In particular, methane generation rates were reduced from 30 to 10 years, thereby improving the capital recovery time by nearly two-thirds. An added bonus was the discovery that accelerated decomposition resulted in better

compaction of the waste in the landfill, thereby extending the landfill life by roughly 20 percent. PIER Renewables is building off of this earlier research with two additional research efforts. Under the SMUD programmatic contract, Yolo County is expanding the bioreactor concept to a full-scale landfill to demonstrate the environmental and commercial viability of the bioreactor approach for use by California's municipalities. Under the Commonwealth programmatic contract, CH2M-Hill is expanding the bioreactor concept as part of a hybrid mini-grid system. Both projects are in the design phase, with project construction slated for 2003.

Developing Distributed Generation Biomass Energy Responsive to Local Needs. Utility-scale biomass plants are good at providing bulk power to the grid. However, many of California's communities face localized problems that may not be addressed well by large biomass plants. For example, large-scale biomass plants may not be suitable for use in urban areas with air quality and land use restrictions. However, these communities often generate quantities of urban wood and yard wastes that require use of scarce landfill capacity. While it may be uneconomical or impractical to transport these biomass residues to a large biomass plant far from the community, they could be used in a smaller facility to generate power for local needs. Similarly, small communities located in rural areas often face air quality issues associated with open-field burning of agricultural residues, or face wildfire risks from overloaded forests. These communities are frequently located at the end of a transmission line branch and are not usually a high priority for a utility upgrade. In these instances, small biomass plants can help provide capacity growth for the area while helping to resolve air quality or wildfire risk concerns. PIER Renewables has worked closely with the DOE to help develop small biomass plants that can provide clean distributed generation options to these communities. Two biomass distributed generation technologies being developed under the program are those from Community Power Corporation (CPC) and FlexEnergy. (See CPC's success story later in this section.)

CPC is developing small biopower systems ranging in size from 15 kW for greenhouse applications to as large as 200 kW for small industrial applications. CPC has successfully demonstrated the grid interconnection of their small modular BioPower system and achieved combined heat and power efficiencies of greater than 60 percent. The grid interconnect demonstration was completed at the Tsemeta Forestry Regeneration Complex, owned and operated by the Hoopa Valley Indian tribe. The Hoopa tribe is investigating commercial installation of a CPC system based on the results of the demonstration. The ability to interconnect to the grid greatly enhances the efforts to bring to the market a family of transportable, distributed generation BioPower systems. In addition, during the course of the demonstration, CPC also showed the system's ability to use three different forms of potentially flamable forest residues, thereby helping to provide a solution to wildfire risks.

FlexEnergy is developing an ultra-clean and dispatchable microturbine that uses biogas fuels with very low energy content. BioPower systems with these characteristics could be used at communities with small landfills, on dairies, and in areas with severe air quality constraints. FlexEnergy successfully demonstrated a proof-of-concept system that used biogas with as little as 15 percent the energy content of natural gas. The Flex-Microturbine has demonstrated it can achieve full power performance (30 kW) on low-Btu gases without any derating of the system. NOx emission levels were below 2 ppm. Consequently, the FlexEnergy system has the ability to meet the 2007 NOx control level established by the California Air Resources Board for distributed generation systems

fueled by waste gases. The successful POC testing has provided sufficient information to enable the design and construction of prototype Flex-Microturbine systems.

Geothermal Energy Progress

At 2,500 MW, California represents over 30 percent of the world's installed geothermal capacity. Nearly 70 percent of California's geothermal generation represents vapor-dominated resources developed at the Geysers. The remaining 30 percent of the installed capacity are liquid-dominated resources scattered across the state. The energy rich vapor-dominated resources found in the Geysers are unique and little, if any, new vapor dominated resources are expected to be found and developed in California. In addition, there has been a decline in electricity production from the Geysers due to a decline in the geothermal reservoirs. However, California has over 3,800 MW of untapped liquid-dominated resources that could be developed in the future. Most of the untapped geothermal capacity is located in Imperial and Modoc counties. To help with future geothermal development, PIER Renewables has focused on the following activities.

Lowering Costs of Geothermal Drilling and Exploration. One of the biggest barriers to developing future geothermal electricity capacity in California is the high cost of drilling and exploring geothermal wells. As part of the effort to lower those costs, Electromagnetic Instruments, Inc. (EMI) completed designing, manufacturing, and field testing of GeoBILT, an innovative geophysical instrument for three-dimensional subsurface imaging. By providing an accurate image of the subsurface features of a geothermal reservoir, GeoBILT reduces the possibility of drilling dry or low-production wells and thus lowers overall project costs. (See Success Stories later in this section.)

Increasing Revenue Streams for Geothermal Energy. Geothermal electricity generation can also be made more cost-effective by developing additional revenue streams that improve power plant economics. Geothermal power plants utilizing liquid-dominated geothermal resources tend to have scaling and clogging issues due to the content of mineral solids (predominately silica) in the fluid. The scaling and clogging eventually cause equipment and well plugging. Silica extraction benefits the operating and maintenance of the electric generation process through the reduction in silica scaling. Silica removal may also reduce down-time costs associated with scale removal, and the need for costly new injection wells. Because of these potential benefits, PIER Renewables has funded Lawrence Livermore National Laboratory (LLNL) to develop commercial technologies to efficiently extract silica from geothermal fluids. The extraction of silica could also favorably impact the economics of geothermal power generation through the sale of the mineral by-product. LLNL is currently working to develop a process to extract useful amorphous silica from the spent geothermal fluids resulting from Mammoth Pacific Limited Partnership's power facilities located in the Casa Diablo Geothermal Field.

Improving Management of Geothermal Resources and Uses. Another issue of importance to California is the decline in the geothermal reservoirs at the Geysers. As more of the resource was harnessed, the reservoir volume declined with the prospect that future electricity production would continue to drop. The geothermal industry has injected wastewater at the Geysers to help increase the volume and mitigate the reduced production. Future injection activities can be made more cost-effective if the injection can be specifically directed to those reservoir zones that are not yet saturated. As a result, PIER Renewables has contracted with Stanford University to develop methods for predicting in-situ saturation zones at the Geysers. Stanford has collected all necessary historical data on geothermal resource

characteristics and is beginning the modeling work to identify the possible saturation zones.

Hydro and Other Water Energy Progress

California has tremendous water resources with a potential generation capacity estimated to be as high as 1,900 MW for hydro (sites with some type of developed impoundment or diversion structure but without existing power generation) and 30–40 kW/m for ocean wave energy off the California coast. To date, the state has approximately 1,360 MW of installed small hydro capacity and 0 MW of installed ocean wave capacity. To help with future hydro development, work in the PIER Renewables area has focused on the following activities.

Researching and Developing a Small Hydro Technology. Because of the high MW potential for electricity generation from hydro sites with some developed impoundment or diversion structure, PIER Renewables has provided funding to PowerWheel Associates for a waterwheel project. The purpose of this project is to prove the technical, economic, and environmental suitability of the PowerWheel technology for converting energy from low-head waterfalls into electricity.

Identifying California's Ocean Wave Resources. An early evaluation of the potential energy in ocean waves off California's northern coast estimates there is an average of 30–40 kW/m of available energy. Harvesting 20 percent of the northern California potential wave energy could provide upwards of 500 MW of electricity per year. For this reason, PIER Renewables has funded San Diego State University to do an ocean wave resource assessment project. This project will conduct an ocean wave energy resource evaluation to determine the potential energy off California's coast and identify potential sites best suited for particular wave energy converter (WEC) technologies being developed. Early evaluations based on SWAN runs indicate the coastline north of Point Conception has very good wave energy-to-electricity potential, but it is not as promising for the coast south of Point Conception. However, south of Point Conception may provide a better wave environment opportunity for offshore ocean water desalination. Cost factors for delivering desalinated water to land will be investigated and reported on in the project final report.

2002 RD&D Awards

Most of 2002 was focused on implementing and managing the programmatic projects let in 2001. However, a solicitation released in 2002 targeted accelerating development of California's biogas energy resources. Biogas resources include gas produced at landfills and biogas generated by livestock operations, wastewater treatment plants, and food-processing facilities. Biogas was targeted for accelerated development for three reasons. First, the uncontrolled release of biogas presents environmental and safety concerns. Fifty percent of biogas is typically made up of methane, a very active greenhouse gas that contributes significantly to the state's global climate change emissions. In addition, uncontrolled release of landfill gas poses explosion hazards, while biogas from livestock operations and wastewater treatment plants is commonly a source of odor and health-related complaints. Second, California has a large inventory of biogas resources that can be easily collected. The state has over 3,000 landfills and transfer stations and over 300 of the landfills are actively receiving wastes. Similarly, California has over 2,000 livestock operations, over 240 wastewater treatment facilities, and over 3,000 food-processing facilities. Each of these facilities contributes to the state's estimated 2 million tons per year of methane gas emissions. Each facility generates the biogas on-site, which means any energy produced from the biogas could be used to meet energy needs of the facility. Third, capturing the biogas generated from these operations can simultaneously provide environmental and energy solutions to the state. For example, advanced biogas

systems employed at California dairies will help address air and water quality concerns related to disposal of dairy manure. At the same time, electricity generated from the system can be used to meet electricity demands at the dairy and reduce its electricity bills. Overall, biogas-to-energy could provide significant benefits to the state in the near term. Successful development of the state's biogas resources could contribute approximately 240 MW of clean and renewable generating capacity.

Five projects totaling nearly $2.4 million received awards under the targeted biogas solicitation:

- **TIAX LLC** of Cupertino received $497,811 to demonstrate a project in a Marysville landfill using hydrogen-based biogas fuel to drive a 75 kW cogeneration unit while reducing NOx emissions.
- **Stearns, Conrad, and Schmidt Consulting Engineers** of Long Beach received $450,000 to demonstrate a new 250 kW microturbine's ability to use landfill gas as fuel.
- **Makel Engineering, Inc.** of Chico received $457,042 to demonstrate a biogas-based engine at Butte County landfill with a greater efficiency while maintaining ultra-low NOx emissions.
- **FlexEnergy, Inc.** of Mission Viejo received $499,548 to demonstrate a flexible microturbine prototype that will run on digester gas at Cal Poly San Luis Obispo and a prototype fueled by landfill waste gas at the Puente Hills landfill outside of Los Angeles.
- **Valley Fig Growers,** a food processor in Fresno, received $476,002 to construct and install an anaerobic digester at its facility. Methane produced will fuel a microturbine that will produce electricity and heat for use at the facility.

Success Stories

Reducing the Costs of Geothermal Exploration and Development: EMI's GeoBILT

Exploration and drilling costs represent the highest costs involved in developing geothermal resources—as much as 50 percent of the total costs. Due to a lack of information about the underground resource, exploration drilling often results in dry or low-production wells, at great expense to the developer.

Electromagnetic Instruments, Inc. (EMI) designed, manufactured, and field-tested an innovative logging tool that can help reduce the uncertainties associated with geothermal exploration and drilling. The Geothermal Borehole Induction Logging Tool (GeoBILT) is a geophysical instrument used for three-dimensional subsurface imaging. Once inserted into a geothermal well, GeoBILT collects data that helps in understanding and mapping the geothermal resource.

EMI's Geothermal Borehole Induction Logging Tool (GeoBILT)

The new tool provides capabilities that are presently unavailable with the commercial logging systems developed for the oil and gas industries. Using insulation and heat dissipation devices, GeoBILT can operate at temperatures up to 260°C and depths up to 4 km. The tool also features a three-component borehole transmitter and a three-component variable offset receiver for collecting nine component "vector" data sets. The data sets are

needed for delineating off-axis structure fractures and reservoir inhomogeneities. GeoBILT also allows for geophysical logging in highly deviated or horizontal boreholes.

The potential benefits of GeoBILT to California's geothermal industry (as well as the oil and gas industries) are significant. The new tool is powerful, versatile, reliable, and easy to use. It provides a significant aid in field characterization for exploration, development, and enhancement. GeoBILT is expected to reduce the expense associated with exploratory well drilling by approximately 20 percent.

Providing Clean Peaking Power to California's Biomass Plants: GTI

California has 39 biomass power plants that supply the state with approximately 700 MW of generating capacity. For the most part, these biomass facilities provide baseload capacity to the grid. Due to their design and the nature of direct combustion of solid fuels, these facilities cannot provide peak capacity to the grid on demand. In addition, the changing moisture content of biomass residues entering the boiler can cause significant derating of the boiler.

By cofiring small amounts of gas (approximately 10 percent of the boiler rating) into the combustion zone, operators can control the usual problems that accompany combustion of wet biomass. Cofiring offers an independently controlled combustion zone with higher temperatures, resulting in faster load response; better burnout; and faster, cleaner startup. In addition, cofiring offers biomass plants the ability to provide up to 10 percent of their power for peaking purposes. These benefits will enable California's biomass plants to compete in today's volatile power market which requires greater responsiveness than is now possible.

Gas Technology Institute (GTI) and Coen developed a low-NOx burner that could be used in California's biomass power plants. Prototype burners were installed and tested in two northern California biomass power plants: Burney Mountain Power and Fairhaven Power. Testing was completed in March 2002. Test results from Burney showed that cofiring will avoid derating of the boiler and generate peak revenues from load dispatch to effectively meet changing power demand. At Fairhaven, cofiring will avoid boiler derating and allow compliance with CO and NOx regulations.

GTI is currently marketing the low-NOx cofiring system for application in California. If deployed on all of California's biomass plants, it would provide additional 90 MW of clean, affordable, and renewable peaking capacity to the state.

Developing Biomass Distributed Generation Systems: CPC's BioPower Unit

Utility-scale biomass plants are a good option for providing baseload capacity to California's electricity system. However, there are a number of California communities where small-scale power plants better address their localized needs and financial situation. The Tsemeta Forest Regeneration Complex in Hoopa, California is a good example. Located at the end of the transmission line and in a remote part of the state, the Hoopa tribe faces future capacity needs that may be difficult to solve with conventional approaches. In addition, the region is considered a wildfire risk due to the large amounts of standing timber. A natural solution would be to use forest thinnings in a small-scale biomass power plant. The generated electricity could help meet local capacity needs, while use of forest thinnings could help reduce wildfire risks.

Community Power Company (CPC) designed, built, and installed its prototype12.5 kW BioPower unit at the Tsemeta Forest Regeneration Complex. The overall goal of the project was to demonstrate that

the BioPower system could displace retail electricity through a combined heat and power application, and collect the data needed to develop the scale-up path to a family of commercially viable systems in California. Testing was completed in 2002. The unit achieved a combined heat and power efficiency of greater than 60 percent and operated solely off of forest thinnings. Based on the results, the Hoopa tribe is investigating commercial installation of a BioPower System. CPC intends to offer the 12.5 kw systems as well as systems up to 200 kw in size. Biomass-distributed generation options like CPC's BioPower system will provide California with the means to use local renewable resources that solve local electricity and environmental problems.

Community Power Company's 12.5 kW BioPower Unit Prototype

Identifying California's Wind Energy Resources: 2002 Wind Maps

A new high-resolution wind resource assessment for California released in December 2002, provides assessment provides capability to assess wind resources anywhere in the state down to a grid size of 200 by 200 meters. The assessment also provides wind speeds at four different hub heights (30, 50, 70, and 100 meters) in response to the move to potentially taller wind turbines. The new wind resource assessment will be critical in helping the Energy Commission and the PUC establish a road map for the RPS. In addition, the wind resource will provide potential wind developers with an easy-to-use tool for gauging the potential for new wind resource development in California.

Establishing California's Wind Energy Performance: 2001 WPRS

In 1984, the Legislature directed the Energy Commission to provide annual reports on the performance of wind energy facilities operating in the state. The Wind Project Performance Reporting System (WPRS) provides information on the performance of wind turbines operating in California, the amount of electricity generated by the turbines, and important information on trends occurring with wind energy systems in the state. The industry has pointed out the importance of the WPRS as a means of measuring the value of wind energy to California's electricity system and assessing necessary technology developments. Prior to PIER Renewables becoming involved with the WPRS, it had been dropped by the Energy Commission due to resource limitations. The last WPRS had been produced in 1995. PIER Renewables made it a priority to bring the WPRS back to life and up-to-date. In October 2001, PIER Renewables published a new WPRS covering 1996–1999. In December 2002, PIER Renewables released the 2000–2001 WPRS.

Providing a Super Market of PV Choices: Schott Applied Power and UNI-SOLAR

Penetrations are problems for PV systems on roofs. Building owners do not want roof leaks; roofers do not warranty their work if penetrations exist. In the past, flat roof PV mounting was done with heavy ballast to hold the systems to the roof, adding additional costs. Schott Applied Power has designed, tested, and is now making available a flat roof mounting system that is self-ballasting and does not require roof penetrations.

Through the SMUD programmatic contract, PIER Renewables is funding this breakthrough project, which brings building designers, architects, and engineers more options for flat roofing and PV.

These systems provide shading for the roof, thus helping to extend the life of the roof, as well as provide for HVAC reductions because of the direct roof heat load reductions—and the costs are reduced from conventional flat roof solutions.

Complete roof coverage with photovoltaics has been difficult to achieve because of weatherproofing at edges, tops, and bottoms. In addition, projects have been building applied, meaning modules sit above weather skins of the buildings.

Schott Applied Power Flat Roof Mounting System

This United Solar project has done what the industry has attempted to accomplish for years—it has produced a truly building-integrated product. This PV system is the weather skin of the building. The image above shows the batten seam clamping method, which sheds water down the slope of the roof. This enables the complete roof to be covered with the thin film amorphous product. Other project advancements include quick disconnects and a roll deployment method that reduces installation time to a matter of hours. These advancements add value to the PV product and reduce the installed costs of systems to grid-connected California utility customers.

Outlook

The RPS will continue to play an important role in the direction of RD&D activities conducted under PIER Renewables. Much of the research work proposed in the near term appears to provide a good road map for identifying ways renewables can be developed and deployed to meet the 20 percent target and the "best-fit, least-cost" approach. Among the research activities proposed for 2003–04 include coordinating with other state agencies and stakeholders in evaluating and modifying the strategic value analysis, in developing new tools for obtaining higher value from renewable resources (e.g., wind forecasting, identifying the cost of integrating renewables into the grid, etc.), and identifying near-term deployment strategies. In addition, research targeted to specific renewable resources will be conducted. Highest priority areas will be identified based on identified RPS strategies and the extent by which the targeted research will help achieve the strategies.

ENVIRONMENTALLY-PREFERRED ADVANCED GENERATION

2002 Progress Update

The PIER Environmentally-Preferred Advanced Generation (EPAG) team is furthering the development of clean and efficient distributed generation (DG) technologies. During 2002, eight new EPAG projects totaling $17,673,802 were funded by the Energy Commission. In addition, at the end of 2002, the EPAG Team was managing 11 ongoing projects and had completed 12 projects since 1997.

Of the eight new projects funded in 2002, six contracts resulted from two RFPs released the previous year by the EPAG team. The first RFP targeted fuel cells, microturbine and small turbine generators, hybrid systems that include a fuel cell or a turbine, and associated technologies. The RFP set forth technology performance targets and stretch goals that were established in consultation with the energy RD&D community and related federal programs. Subsequently, the Energy Commission approved nine proposals for funding awards. Five of these proposals were funded in 2001, and the remaining four in 2002.

The second RFP, the Advanced Reciprocating Internal Combustion Engine (ARICE) RFP, targeted atmospheric emission reductions, efficiency improvements, and improved durability from reciprocating engine systems. The installed capacity of reciprocating engines in California may be as high as 8,000 MW, used primarily for standby power. Operational hours are limited because of high NOx emissions. Performance targets for the RFP were formulated through the formation of the California ARICE collaborative which includes representatives from local, state, and federal government agencies; engine manufacturers; fuel suppliers; utilities; universities; national laboratories; and environmental groups. The RFP was released on December 7, 2001. In 2002, the Energy Commission approved funding for two contracts. EPAG staff will seek approval to fund a third contract in early 2003.

The remaining two projects were for a combined heat and power (CHP) industrial gas turbine demonstration at a state facility using a very low-NOx combustion technology developed through earlier EPAG projects, and a jointly funded project with DOE to complete separate engineering and economic studies for the installation of CHP technologies at three federal facilities in California.

EPAG is the technical manager for a collaborative DOE/multistate project to develop nationally accepted performance testing protocols for DG systems for both field and laboratory installations. The project is a follow-on to an EPAG contract with the University of California of Irvine to develop laboratory-scale performance testing protocols for microturbine generators. The new project is coordinated through the Association of State Energy Research and Technology Transfer Institutions (ASERTTI), the New York State Energy Research and Development Authority, and the Illinois Department of Commerce and Commercial Affairs. The project is funded through a $1 million award from DOE, and at least $3 million in match funding from the state participants. The project will develop testing procedures, verify the procedures through application to DG systems in both laboratory and field installations, and compile testing results into an Internet-accessible database. Results for DG system testing will provide potential end users with uniform, independent performance information.

The EPAG team is facilitating the installation of DG technologies through technical support to state agencies and is providing technical expertise and assistance to local government entities that will demonstrate and install fuel cells. These entities include the California Environmental Protection Agency, the California Air Resources Board, the California Power Authority, and the South Coast Air Quality Management District.

The EPAG team is co-funding projects at the Electric Power Research Institute and Gas Technology Institute that will help to define and augment EPAG goals, program plans, and existing projects. The team also provides information on the status of technology development by other research organizations, which is useful for coordinating jointly funded projects, planning future EPAG research activities, and reducing possible duplication of effort.

2002 RD&D Awards

Four contracts were approved following a solicitation for RD&D proposals concerning fuel cells, microturbines, and small turbines. The goals of these individual contracts include:

- Reduce NOx emissions in a 7.5 MW, single-can combustor industrial gas turbine to less than 3 ppm by means of clean combustion technologies that eliminate the need for selective catalytic reduction (SCR) or other exhaust gas cleanup. The contractor will select from among three possible combustion systems and carry that one through to an engine test.
- Develop a cost-effective catalytic combustion

system for a larger, more complex, multican combustor gas turbine that will yield NOx emissions of less than 3 ppm, without post-combustion emissions controls. The contractor will select a turbine manufacturer as a partner for conducting an engine test.

- Develop and demonstrate at a California industrial facility, a gas turbine with the combustor replaced by a unique partial oxidation reactor. The turbine exhaust is a hydrogen-rich fuel gas suitable for fuel cells, furnaces, or boilers. The resulting hybrids or CHP systems will have efficiencies up to 88 percent and very low emissions.
- Design, construct and operate a unique, low-temperature, 1—3 kW module for a 10–100 kW solid oxide fuel cell. The focus will be on radiative and convective heat transfer, thermal and load cycling performance, reliability, and high efficiency. The efficiency goal is 55 percent, plus 25 percent in high-quality heat, with negligible emissions.

Two contracts were approved following a solicitation for RD&D proposals concerning ARICE technologies. These contracts will develop and demonstrate advanced engine technologies that will be integrated into commercially available engines within two to three years. The technologies include (1) homogenous charge compression ignition; and (2) on-board natural gas reforming using engine exhaust heat to generate hydrogen to facilitate lean combustion, enhance exhaust gas recirculation, and treat catalytic exhaust. The near-term goals of both projects are to:

- Improve engine efficiency by 30 percent
- Reduce NOx emissions more than 100-fold (from more than 2.0 g/bhp-hr currently, to less than 0.015 g/bhp-hr)
- Reduce or maintain current total installed cost ($700/kW) and operating and maintenance (O&M) cost ($0.005/kWh), which are the lowest among all DG technologies currently available
- Improve or maintain current durability, reliability, and availability.

One project, a joint funding grant agreement with DOE, was approved to evaluate the feasibility and facilitate the implementation of advanced CHP technologies at federal sites. This project will:

- Develop site-specific CHP implementation plans at three separate federal sites in California to increase the transferability of the results to other facilities. The three sites will be located in different regions of the state, have different operating characteristics, and will use different CHP technologies.
- Test the performance evaluation protocols for advanced CHP technologies developed by the Energy Commission.

The last EPAG award is an interagency agreement for a small turbine generator demonstration project. This project has the following goal:

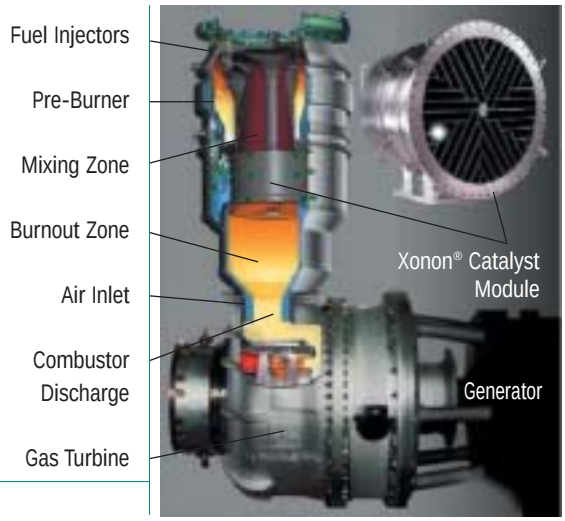
- Demonstrate, for the first time in a commercial CHP application, a catalytic combustor-fired 1.4 MW gas turbine with NOx emissions less than 2.5 ppm. The combustor eliminates the need for selective catalytic reduction (SCR) or other exhaust gas cleanup technologies. This system has been operating since November 2002 with no combustor- or turbine-related downtime, and with NOx emissions exceeding expectations at less than 1 ppm.

Success Story

Ultra-low Emissions Combustion System for Power Plants

The Xonon® Cool Combustion system developed by Catalytica Energy Systems significantly reduces NOx formation during fuel combustion in a gas turbine combustor. The goal of two prior EPAG-funded projects was to virtually eliminate the formation of NOx, a primary contributor to smog, while also reducing other pollutants. This breakthrough technology is now being successfully demonstrated

in a commercial, distributed generation, CHP power plant operated by the Sonoma Developmental Center, a state facility in northern California. A Xonon®-equipped 1.4 MW Kawasaki gas turbine has been providing steam and electricity to this facility since November 2002, with NOx levels below 1 ppm. This is less than the emissions of central station power facilities, without resorting to SCR or other post combustion control technologies, which require large, expensive installations and the use of toxic chemicals. The next phase in this continuing PIER/EPAG technology development will be a successful demonstration in a larger, more complex gas turbine installation suitable for central station generation. This should establish a new standard for power production in California.



Catalytica's Xonon® Cool Combustion System on a 1.4 MW Kawasaki Turbine

Outlook

In 2003 the EPAG team will continue contract management activities, technology scoping studies, proposal evaluation and contract funding, collaborative activities, and technical support for research projects. Specific activities are divided into EPAG's five core research areas and are summarized below.

Develop Combined Heat and Power Capabilities

CHP, also called cogeneration, is the beneficial use of both the electricity and waste heat from a generating system. Thermodynamic considerations put highest priority on achieving high electrical generation efficiency. The use of waste heat for water, space, or industrial process heating, or for cooling by means of absorption chilling, improves the value of the generating system, reduces emissions, improves overall fuel efficiency, and lowers costs to the system owner. The EPAG team will complete a technology scoping study, prepare specific technology targets and stretch goals, conduct a public workshop to receive comment on these targets and goals, and then release an RFP and fund projects that will enhance the value of EPAG technologies through cost-effective CHP designs and systems. This RFP will be coordinated with the efforts of the U.S. EPA, DOE, other state agencies, and industry.

Develop Electricity Generation Using Advanced Turbine Technologies

EPAG plans to demonstrate two types of catalytic combustor-fired gas turbine: a turbine with a multican combustor, and a single-can industrial/utility-scale turbine. EPAG has funded a series of projects since 1997 to help develop this technology, which enables gas turbines to reduce NOx emissions to less than 3 ppm without the expense, hazards, and reliability problems associated with exhaust gas cleanup systems. The first commercial—and highly successful—demonstration of this technology commenced operation late in 2002 in a small, 1.4 MW turbine. Completion of this RD&D effort will be realized with the commercial demonstration of catalytic combustor-fired turbines that are larger, more complex, and have multican combustors similar to those used in central station gas turbines. This

second demonstration should open the market for catalytic combustors to a broad spectrum of large turbines from many manufacturers.

EPAG also plans to augment pre-installation testing of a natural gas–fired, zero emission combustor that will drive a steam turbine and generator at a demonstration power plant. In addition to emitting no pollutants, the CO_2 (a major greenhouse gas) from this system will be easily collected for commercial use or sequestration.

EPAG will initiate a new project with Ramgen Power Systems to develop and demonstrate a unique technology for DG applications. Ramgen will combine the ramjet, a supersonic high-pressure compressor technology, with a gas turbine to achieve up to 45 percent efficiency and less than 10 ppm NOx. The project will be jointly funded by EPAG and DOE's National Energy Technology Laboratory.

Develop Advanced Reciprocating Internal Combustion Engines

EPAG staff will seek funding approval for an advanced laser ignition system (ALIS) project. This is the third project resulting from the ARICE RFP released late in 2001,and has been slightly modified based on DOE's Advanced Ignition Roundtable held in October 2002. The ALIS project is being supported by a consortium assembled by DOE's Argonne National Laboratory. When coupled with other advanced engine technologies, the advanced laser ignition system will achieve near-term goals similar to those described above for the other two ARICE projects. When integrated with the particular technologies to be developed in the other two projects, ALIS will provide ultra-clean (NOx below 0.01 g/bhp-hr) and very efficient (over 50 percent) engines for DG in California within three to four years.

EPAG will also continue coordinating its ARICE program with DOE's advanced reciprocating engine systems (ARES) program to achieve common goals.

Develop Fuel Cell and Fuel Cell/Turbine Hybrid Technologies

EPAG will demonstrate these systems in collaboration with the Gas Technology Institute (GTI) and the South Coast Air Quality Management District (SCAQMD). EPAG is a member of GTI's Distributed Generation Mutual Fund, whose dozen-plus participants co-fund demonstrations of solid oxide and proton exchange membrane fuel cells and microturbine generators, and other DG-related activities. In addition, EPAG is assisting in the review of fuel cell and fuel cell hybrid proposals submitted in response to a $1 million SCAQMD RFP. EPAG will consider co-funding some of the demonstrations that have technical merit, are consistent with EPAG objectives, and cannot be fully funded by SCAQMD. This authority is part of the Energy Commission/PIER support of the California Stationary Fuel Cell Collaborative.

Research Collaboration

EPAG will continue to be the technical lead for the ASERTTI DG performance testing protocol development project. EPAG will support coordination among ASERTTI management and its contractors, state members of the collaborative and their contractors, and DOE. EPAG will develop specific contracts for ASERTTI contractors, including GTI, Underwriters Laboratory, and the Southern Research Institute. EPAG will host an ASERTTI program steering committee coordination meeting and kickoff meeting for the new ASERTTI contractors.

EPAG will also coordinate with the PIER Energy Systems Integration (ESI) team and its contractors on their distributed utility integration test (DUIT)

and FOCUS-interconnection II (FOCUS II) projects. These ESI contracts provide part of the match funding for the ASERTTI DG performance testing protocol development project described earlier. One purpose of the DUIT project is to measure the interaction between multiple DG technologies and the utility distribution system. The purpose of FOCUS II is to assess the interaction of DG systems with the utility grid. Both ESI projects relate to the electrical performance testing in the ASERTTI project. Supplemental EPAG funding will identify the linkage between the ESI projects and the ASERTTI project, and augment the ESI contracts for additional specific testing.

ENERGY-RELATED ENVIRONMENTAL RESEARCH

2002 Progress Update

Protecting and improving the environment is a major element of planning in each of the six subject areas of the PIER program. The mission of PIER is to conduct energy research to improve quality of life by "…providing *environmentally sound*, *safe*, reliable, and affordable energy services and products…" [emphasis added]. The research conducted in PIER Environmental Area (PIEREA) is cross-cutting, and therefore an integrating element for the broader PIER program. In addition to addressing suspected and documented environmental impacts of electricity, PIEREA uses a multimedia approach to providing basic scientific information and tools for understanding the environmental implications of related technology and fuel choices that may be undertaken elsewhere in the PIER program.

Based on the goals and objectives outlined in the 2001 PIER Environmental Area Research Plan, PIEREA supports numerous research initiatives designed to mitigate electricity system-related environmental impacts. These initiatives address critical research needs of the four identified energy-related environmental subject areas of air quality, aquatic resources, land use and habitat, and global climate change—and include the following examples:

- Under the *Fine and Ultrafine Particulate Matter Study*, researchers tested an improved particulate matter (PM) monitor on four combustion systems (including a natural gas–fired turbine), to develop a more accurate reference test method. Emissions of fine particulate ($PM_{2.5}$) from the one natural gas–fired turbine tested were found to be about 4 percent of the emissions estimates published by the EPA; coarse particulate matter emissions (PM_{10}) were found to be about half of the EPA published emission factor. Given these significantly reduced anticipated emissions, it may be easier to site power plants, and it may be possible to reduce power plant construction costs.
- Another project initiated late in 2002—*The Ecological Effects of Pulsed Flows on Aquatic Communities*—is funding research to identify the biological effects of abrupt, abundant releases from hydropower plants into rivers. Although the state benefits from the on-demand electricity that these releases generate, the consequences to downstream aquatic life are unknown. Impacts from pulsed flows may cause scouring and stranding of shallow water-dependent aquatic ecosystems, selective displacement of fish populations based upon size and age, and siltation or coating of gravels used by salmon for spawning. For example, amphibian eggs laid just below water surface level may be left exposed during low flow periods or washed away during high flow periods. By studying the effects from these releases, information is developed to allow the Department of Fish and Game, the Department of Forestry, and the Federal Energy Regulatory Commission (FERC) to minimize impacts to aquatic environments while maximizing generation from hydropower facilities.
- PIEREA is funding the project *Developing*

Methods to Reduce Bird Fatalities in the Altamont Pass Wind Resource Area (APWRA). Researchers estimate that more than 1,000 birds are killed at the APWRA annually, including a significant number of protected raptors. Preliminary research results suggest that 25 percent of the turbines are responsible for nearly all of the bird mortality. This project is systematically surveying samples of all wind turbine types and topographical features found at APWRA to determine relative collision risk to birds. Patterns of risk factors are emerging that will enable the wind industry to site turbines—including the new, higher-generating designs in low bird-collision risk areas—thus protecting birds while increasing the generating capacity of wind energy in the state. The product of this study is a risk assessment model that will allow the industry and regulators to improve turbine siting, remove the moratorium on re-powering, and ultimately open larger areas of the APWRA.

- To address the lack of long-term meteorological and hydrological data necessary for measuring climate change, PIER is funding development of low-cost environmental monitors and locating monitoring systems in key regions that modeling suggests will provide early indicators of the climate change signal. This system will enable scientists to study these natural processes and collect the data necessary to develop improved regional climate change models. These models are key to identifying physical impacts such as climate change impacts to water supply in California. Further, the data and models will be used to develop appropriate adaptation/mitigation policy responses to protect California's environment and economy.
- PIEREA completed the *Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999*, which updated the Energy Commission's 1998 inventory report. This report, which is mandated by the legislation that created the California Climate Action Registry (SB 1771), quantifies greenhouse gas emissions and their sources, and compares California's emissions with other states and nations. The inventory was developed using new guidelines adopted by the Intergovernmental Panel on Climate Change, and is consistent with methods used to conduct the national inventory prepared by the EPA.

PIER Environmental Area staff continued to develop and complete the research road maps that address high-priority environmental issues associated with the distribution, generation, and transmission of California's electricity. Three road maps were completed: *A Road Map for PIER Research on Avian Collision with Power Lines in California; A Road Map for PIER Research on Avian Collision with Wind Turbines in California;* and *A Road Map for PIER Research on Avian Power Line Electrocution in California.*

Three other road maps will be finalized very early in 2003: *PIEREA Climate Change Research, Development, and Demonstration Plan; A Road Map for PIER Research on Fish Passage at California Hydropower Facilities;* and *A Road Map for PIER Research on Hydropower's Influence on California Water Quality*. Additional road maps are being developed on distributed generation, energy efficiency and load management, environmental justice, the impacts of power line corridors on environmental quality, and instream flows necessary to support aquatic biota and habitat.

2002 RD&D Awards

Integrated Forecast and Reservoir Management (INFORM)

A significant portion of hydropower within the state is generated from water discharged from multipurpose dams, such as Lake Shasta or Oroville. The amount of hydropower generated at such multipurpose dams in any given year is based on the amount of runoff as well as meeting competing

water supply, flood control, and other environmental requirements. To maximize power generation and water supplies while meeting flood control and other needs, operators must be able to accurately predict runoff on a daily, weekly, monthly, and yearly basis. Through this project, PIEREA and the Hydrologic Research Center will help managers with improved runoff forecasting by demonstrating an integrated management system for reservoir operation that incorporates global climate model forecasts at the Folsom, Oroville, Shasta, and Trinity reservoirs. Enhanced runoff forecasting should enable hydropower plant operators to improve hydropower production at California hydropower facilities without increasing water supplies or infrastructure.

The Ecological Effects of Pulsed Flows on Aquatic Communities

California's in-state hydropower plants compose approximately 27 percent of our in-state generation capacity. The majority of this capacity is associated with dams that can quickly discharge stored water to generate electricity during peak demand periods. In this project, PIEREA and the Center for Aquatic Biology and Aquaculture (CABA) at UC Davis will develop a scientific framework for assessing possible short- and long-term ecological impacts of pulsed flow releases on California stream systems regulated for hydropower production. This work will help to improve and maintain the health of associated aquatic environments.

Development of Portable Ambient and Indoor Air Monitors

This collaborative effort among the Energy Commission, the Air Resources Board (ARB) and New York State Energy Research and Development Authority (NYSERDA) will research, develop, and demonstrate portable, relatively inexpensive, real-time ambient and indoor air monitors. The Energy Commission has a responsibility to ensure that indoor air is not adversely affected by energy efficiency measures that it recommends or mandates (such as building ventilation standards), and must consider the impacts to nearby communities (e.g., environmental justice evaluations) when siting proposed power plants. These instruments will allow for more intensive monitoring of indoor environments and more site-specific monitoring for siting of power plants. The monitors developed through these projects will be instrumental in assessing impacts and the regulatory decision-making required for developing appropriate regulations and permit conditions necessary to protect public health. This work is also being done in consultation and collaboration with the Buildings Efficiency team.

Improvement of Short-Range Dispersion Models to Estimate the Air Quality Impact of Power Plants in Urban Environments

Since 1999, more than 30 power plants have been built or are under construction in California. When siting new power plants, the Energy Commission assesses the potential impacts of additional air emissions from the plant on the local community. However, existing models were not developed for urban environments (where many power plants are sited).

To improve the accuracy of dispersion modeling in urban areas, the Energy Commission is working with the ARB to conduct tracer studies in Wilmington, which is in the Los Angeles area. These studies look at releases of pollutants from elevated and ground-level sources and study ways to develop and validate components to be used in dispersion models to estimate the impact of elevated and ground-level sources. In the context of permitting proposed plants, the development of these models will improve the ability of local air pollution control districts and the Energy Commission to estimate these impacts and trade-offs between control and measures proposed for impact mitigation.

Avian–Transmission System Mitigation Program

Avian interactions with utility structures can result in negative impacts such as costly power outages and violations of state and federal laws. PIEREA is working with Santa Cruz Predatory Bird Research Group to implement an Avian–Transmission System Mitigation Program. This program will conduct research that supports the development and application of methods and technologies for reducing and resolving negative impacts from avian interactions with utility structures.

Baseline, Classification, Quantification, and Measurement of Carbon Market Opportunities in California

Significant levels of CO_2 —the most important green-house gas (GHG)—in the atmosphere contribute to climate change. One particularly promising option to reduce atmospheric CO_2 levels is carbon sequestration in terrestrial ecosystems, which is removal of atmospheric carbon dioxide into persistent pools of above- and below-ground vegetation and soil carbon. PIEREA, EPRI, and Winrock International are working together to provide science-based, peer-reviewed tools, data sets, and methodologies to evaluate and formulate carbon strategies and design and implement practical near-term projects. These improvements will increase understanding of how much carbon can be stored or avoided for various classes of projects in California, and at what cost. When taking into account secondary benefits, forestry and land-use change projects are expected to be among the least-cost, near-term options for reducing GHGs in the atmosphere. California has a variety of options for sequestering carbon, and changes in state land use and management could store significant amounts. When combined with the results of other related studies, this study will provide valuable insight into the least-cost options available for offsetting the emissions of CO_2 as may be required in the future by international agreements such as the Kyoto Protocol.

California Environmental Sensing and Communications

PIEREA is working with the Scripps Institution of Oceanography, the National Science Foundation and the National Oceanic and Atmospheric Administration (NOAA) to develop and test high-quality, low-cost, and reliable remote environmental monitors. These monitors will measure, in real-time or near real-time, important environmental variables including precipitation, wind velocity, and snow cover in key remote locations. The data collected under this and subsequent projects will have multiple applications, such as the development and validation of regional and hydrological models, which will be used to improve the predictions of climate-induced physical impacts such as future availability of hydropower production.

Greenhouse Gas Emissions Inventory

Research indicates that emissions of greenhouse gases from human activities have been steadily increasing since the industrial revolution, leading to global warming. This project, in compliance with the SB 1771, updates the Energy Commission's 1998 Emissions Inventory report. Power plants contribute about 16 percent of the in-state carbon dioxide emissions from the combustion of fossil fuels. If emissions of out-of-state power plants serving California are included in the inventory, power plant emissions represent about 28 percent of the total emissions. This inventory serves as a primary reference for greenhouse gas emissions and their sources, estimates the impacts of past energy and air quality policy and programs on emissions, and provides a valuable benchmark by comparing emissions relative to states and other representative nations and reductions required by the Kyoto Protocol.

Success Stories

Global Climate Change

GHG emissions are contributing to an unprecedented rate of global warming. Global average surface temperatures are expected to increase by 2.5–10.4°F over the period of 1990 to 2100. This rise is likely to affect the location, frequency, form (rain or snow), and amount of rainfall, as well as energy supply and consumption, vegetation distribution, crop production, coastal structures and ecosystems, water resources, human health, and other sectors. In the past year, PIEREA has funded research to estimate the potential impacts of climate change on California.

These simulations have already provided new information. For example, PIEREA worked with Yale University to model potential changes in residential and commercial net energy expenditures as a result of climate change on California indoor heating and cooling usage patterns. Modeling results indicated that by 2100, a 2.7–9°F (1.5–5°C) warming would cause an estimated $1.3–17.8 billion annual increase in energy expenditures for cooling, which far outweighs any offset from a reduced heating demand. An increased cooling demand is especially problematic, because it will occur on hot summer days, when the electricity system is under its greatest stress. If verified, damages on the order of $1 billion a year can be expected as soon as 2023.

In another project, PIEREA, Oregon State University, and others used a state-of-the-science dynamic vegetation model at relatively high spatial resolution to estimate changes in the location and productivity of terrestrial vegetation. Researchers modeled a higher number of vegetation types than ever before and coordinated the effort with projections of future urban development, to explore the combined effect of climate change and urban development on ecosystems. Results for one ecosystem type suggest that the combined effect of urbanization and a changing climate may negate ongoing ecological conservation efforts.

Other PIEREA efforts in this area are modeling the impacts of climate change on crop yields and agricultural water use in California, the economic impacts of sea-level rise on coastal structures, and the impact of climate change on water resources, including hydropower production. The California Department of Water Resources will consider these studies in preparing of its 2003 State Water Plan.

Measuring and Characterizing Fine and Ultrafine Particulate from Power Plants

Combustion power plants and other sources introduce particulate matter (PM) into the air—both by direct emissions and through chemical reactions. Exposure to PM can aggravate respiratory problems; decrease lung function; affect the development of the respiratory, nervous, endocrine, and immune systems; and increase cancer risk.

In 1997, the EPA enacted new ambient air standards for particulate matter, including those with a diameter smaller than 2.5 microns ($PM_{2.5}$), because they can lodge deep in the lung, increasing health risks. However, there are problems measuring PM. Traditional methods to measure air emissions from stationary sources, such as power plants, tend to underestimate or overestimate the source's contribution to ambient aerosols, because they do not properly account for aerosol formation that occurs after the gases leave the stack. These aerosols constitute a portion of the particulate from power plants. Moreover, there are few data regarding emissions and characteristics of fine aerosols from power plant and oil and gas industry combustion sources, and the available information is outdated.

This program estimated average emission rates of PM from a given source (i.e., emission factors) and identified the chemical composition of the fine PM

emitted (i.e., speciation profiles), especially for organic aerosols. Researchers also identified and characterized $PM_{2.5}$ precursor compound emissions—that is, emissions that can combine to form the aerosols. Finally, this project compared dilution and fractional sampling methods for $PM_{2.5}$ measurements. Researchers measured particulates at the stack, using both a dilution tunnel research test method and the traditional accepted regulatory methods. Emissions of fine particulate ($PM_{2.5}$) from the one natural gas–fired turbine tested were found to be about *only 4 percent* of the number given in *U.S. EPA Compilation of Air Pollutant Emission Factors*. Unlike the traditional methods, results from the dilution tunnel method are directly comparable with ambient air data. Pilot scale evaluation and additional testing will advance understanding of other differences between the methods.

These tests provide reliable source emissions data for use in assessing the contribution of oil, gas, and power generation industry combustion sources to ambient $PM_{2.5}$ concentrations. The test method(s) will help regulators and researchers design and implement future PM mitigation strategies and better characterize the risk posed by gas turbines. These data will also help power plant operators identify appropriate PM control measures.

Spray Enhancement of Dry Cooling

Power plant dry cooling technologies can significantly reduce a plant's water demand; however, they can also limit its electricity output during the hottest days of the year, when demand is the highest—a serious drawback that could prevent their widespread use.

Water shortfalls of 2.4 million acre-feet are expected in California by 2020. On average, a typical 500 MW, combined-cycled power plant employing wet cooling technology requires 3 million gallons of water per day (gpd), almost entirely for cooling. The same size facility using dry cooling reduces water use by about 95 percent—a savings of 2.85 million gpd. This savings could help reduce shortfalls and meet the water demands of more than 12,000 people—nearly enough to supply a city the size of Auburn, California.

Spray Enhancement at Crockett Cogeneration Plant (photo courtesy of J. Maulbetsch)

To mitigate reduced electricity production, a small amount of water can be sprayed into the cooling tower's inlet air stream, where it evaporates and cools the air. Reducing inlet air temperature, even by a few degrees, can restore much of the lost capacity. PIEREA and EPRI evaluated the performance, costs, and potential problems associated with this strategy at the Crockett Cogeneration Facility, a 240 MW power plant in Crockett, California. The study demonstrated that spray enhancement can significantly improve the performance of dry cooling technology. The study estimates that on hot days, this spray technique will enable the plant to generate an extra 7–15 MW of electricity. This technique drastically decreases power plant water consumption, adds electricity to the grid, has a low initial cost, and can be used to retrofit existing units. Spray enhancement makes it possible to use dry cooling successfully, thus making valuable water available for agriculture, commerce, and residences. Based on these promising preliminary results, next year PIEREA will conduct the next phase of research: a full-scale spray enhancement demonstration in a desert region.

Water Quality Parameters for Cooling Towers

California's per-capita water consumption is rising at the same time that its population is growing and its water resources are shrinking. The state's allocation from the Colorado River has been reduced, and competing interests for water are growing—with power plants the largest industrial water user. California's in-state fossil power plants used between 1.4 and 1.5 trillion gallons of water to generate electricity in 2001. California now requires power plants and other industries to use degraded water (sources that contain naturally occurring or human-induced pollution) whenever possible. Use of degraded water frees a greater amount of freshwater to be used for more appropriate applications, such as human consumption, aquatic habitat vitality, and agricultural irrigation.

Cooling towers can use up to 95 percent of the total water used by a power plant. The majority of California power plants use efficient closed-loop cooling systems that recirculate cooling water. However, degraded water can increase scaling, corrosion, and biofouling in cooling equipment, and create environmental problems in the area where it is eventually discharged. Increased scale deposits of just 1/8-inch can reduce the efficiency of a cooling tower heat exchanger by 40 percent—greatly reducing the amount of electricity that can be generated from the same amount of fuel. In addition, equipment damage and efficiency reductions increase energy companies' operation and maintenance costs and can force outages; poor quality cooling water can affect occupational health.

The water quality parameters (e.g., guidelines on temperature, pH, and mineral content) in current use by power plant operators have become outdated, because they do not satisfactorily account for the use of degraded water, technological innovations, and newer, more stringent regulations. To update these guidelines, PIEREA and EPRI reexamined cooling water quality standards in the context of current practices and regulations, and developed new water quality parameters that take into account recent developments in technology and cooling water treatment. These updated parameters will help operators reduce operational problems associated with the use of degraded water and should increase the use of degraded water for power plant cooling, which will conserve California's limited freshwater supplies. A 500 MW combined cycle power plant utilizing these parameters would reduce freshwater use by approximately 3 million gallons per day.

Outlook

In 2002, PIEREA continued to develop research road maps and projects designed to address the high-priority issues identified in the *PIER Environmental Area Research Plan*. In 2003, PIEREA will continue to address these issues, building upon the foundation that has already been established. The following paragraphs discuss the outlook for PIEREA's funded 2003 research.

Aquatic Resources

Reducing Power Plant Cooling Water Use. As indicated previously, California is likely to face annual shortfalls of 2–4 million acre-feet of water within the next 20 years. To minimize the use of California's freshwater supplies for electricity generation, PIEREA will research the use of water-conserving power plant cooling technologies and non-freshwater cooling supplies. Research may include a full-scale demonstration of spray enhancement of dry cooling, development of new spray nozzles, and assessment of the use of heat transfer fluids other than water for cooling.

Identifying and Mitigating Hydropower Effects on Aquatic Resources. More than half of the state's hydropower capacity was developed before modern environmental regulations. The construction of dams for hydropower and other purposes contributed to the loss of approximately 95 percent of chinook salmon habitat. Now the Federal

Energy Regulatory Commission (FERC) enforces compliance with environmental regulations through its relicensing processes. Hydropower represents approximately 27 percent of California's in-state electricity generation, and over 3,000 MW of that capacity will be up for relicensing before the end of 2010. To reduce the environmental effects of hydropower while maximizing hydropower generation, PIEREA will conduct research to (1) identify and mitigate hydropower effects on aquatic resources, and (2) increase hydropower production without additional environmental impacts. Efforts will improve identification and quantification of downstream flows necessary to support aquatic life and research improved runoff forecasting to maximize hydropower production while protecting environmental resources.

Land Use and Habitat

Environmental Impacts of Power Line Corridors. Tens of thousands of miles of power line corridors that traverse California and constitute critical energy infrastructure can influence ecosystem integrity and function. Habitat fragmentation and loss, and invasion by exotic species, are the most critical factors causing species endangerment and negative impacts to biodiversity. Right-of-way corridors can contribute to each of these. However, opportunities exist to promote biological conservation while maintaining system reliability and to proactively guide the siting of new and repowering projects. In addition, managing habitat to promote biodiversity could transform the public's negative perception about locating transmission lines in local neighborhoods. Projects to address these issues will include an inventory and assessment of conservation opportunities along the state's power line corridors, and research to determine biologically sound routes for future siting and system upgrades.

Evaluation of Biological Impacts Associated with Harvesting Forest Fuels for Biomass Generation. Forest biomass provides a renewable energy fuel source and a disposal option for residues from forest thinning. Harvesting the fuels can provide environmental benefits, such as fire suppression, but also result in negative impacts, such as disruptions to primary productivity and reduction in specialized habitats. Building upon the PIER Renewable program's project to assess California's available biomass resources and fuel supply issues, PIEREA will evaluate both the positive and negative impacts of harvesting forest fuels and developing biologically sound procedures and thresholds. Projects will include an assessment of forest species potentially affected by forest fuel harvesting, and development of procedures and thresholds for conducting environmentally sound forest fuel harvest practices.

Avian Interactions with Utility Structures, Phase II. Avian electrocution and collision with the state's transmission system results in hundreds of thousands of annual bird deaths, power outages, repair costs, legal fines, and reduced energy capacity. PIEREA is funding research to evaluate fatality risk of structures, develop tools to prevent risk, and provide education and outreach necessary to deliver that information to the market. Phase II of this project will field test the tools and models developed in Phase I. Projects will focus on compliance monitoring of the risk assessment model to reduce bird collisions with the larger, high-generating wind turbines, and stratified sample field testing of pole-insulating devices and bird flight diverters.

Air Quality

Urban Heat Island Impacts. Urban air temperatures can be 2–10°F hotter than the surrounding areas on hot summer days, because of the abundance of buildings and roads. The higher temperatures in these "urban heat islands" can increase air conditioning use, requiring more electricity and, as a result, increasing fossil fuel power plant emissions (including ozone precursors and greenhouse gases). Higher temperatures also

increase emissions of other ozone precursors, which enhance the formation of smog and adversely impact urban air quality. PIEREA will conduct a project to develop, test, and operate a new heat island–reduction modeling method that can be used to help California reduce energy use and reach or maintain ambient air quality standards. This study will assess potential energy reductions and ozone air quality improvements from these heat island–reduction measures.

Indoor Air Quality (IAQ). State and federal comparative risk studies consistently rank indoor air pollution among the top four environmental problems. California residents spend an average of 87 percent of their time indoors and, in many cases, the indoor air is worse than that outside. Not only does indoor air contain gases or particles that can harm your health, it is estimated that health effects from these pollutants cost Californians at least $2–5 billion per year. PIEREA will develop information that can be used to better understand and quantify the relationship between IAQ and energy use, and provide guidance for achieving both improved indoor energy efficiency and improved IAQ. Research will focus on information needed to understand (1) the sources of indoor air pollution, (2) how emissions from those sources relate to energy consumption, and (3) approaches for improving IAQ while reducing energy consumption. This program activity will be coordinated with the Buildings Efficiency team.

Life-Cycle Analysis of Distributed Generation. With an increasing electricity demand and distribution system constraints in California, distributed generation (DG) is likely to be a significant factor in meeting new electricity production needs. However, the impact of many small generation units operating in populated areas and releasing ground-level pollutants is not well characterized. A significant addition of combustion DG units in California has the potential to negatively affect local and regional air quality, water quality, solid waste systems, and ecosystems, as well as increase noise pollution. It is important to understand these impacts before DG is deployed on a large scale. PIEREA will identify life-cycle impacts of existing and emerging DG technologies, from materials manufacturing and construction (including energy use and environmental impacts) through operation and disposal of the unit (including landfill, water quality, and soil quality impacts). Researchers will use life-cycle impacts of traditional combined-cycle natural gas central power plants as a benchmark for identifying DG impacts. Researchers will also evaluate the potential short- and long-range air quality impacts of a significant number of DG units, and collect data on the fuel streams associated with various types of DG units.

Global Climate Change

California Research Center on Climate Change. The Energy Commission is creating a virtual California Research Center on Climate Change to coordinate and implement the PIER long-term climate change research plan and improve understanding of how California climate may change with the expected increase of greenhouse gases in the atmosphere. Scripps Institution of Oceanography (Scripps), the University of California at Berkeley (UCB), and participants in a competitive solicitation grant program will conduct the research activities funded by PIER. Scripps will conduct the climate monitoring, analyses, and modeling work identified in the PIER research plan. It will install meteorological and hydrological instruments in the Santa Margarita Ecological Reserve; develop a comprehensive database with 100-year state historical climate data that will be available for trend analyses and future model evaluations; perform a preliminary analysis of how large

features of climate (e.g., the pacific decadal oscillation) affect climate in California; and, perform some preliminary climate modeling analyses for California at the highest level of geographical resolution (10 km) ever attempted in the state. UCB will implement the portion of the plan dealing with economic issues. The competitive solicitation grant program should be in operation by the middle of 2003.

Carbon Sequestration in Agricultural Soils. PIER, the Kearney Foundation, and the California Department of Food and Agriculture will sponsor a project designed to investigate the costs and benefits associated with carbon sequestration in agricultural soils. By identifying the optimal carbon techniques for a region, this project will begin to develop a practical means for offsetting carbon releases from California's fossil-fuel power plants. In addition, many carbon sequestration strategies have collateral environmental benefits, such as improved habitat, soil, and water quality; decreased water and pesticide use; and more sustainable land use and food production.

Exploratory Grant Program

In January 2003, PIEREA issued an RFP through its exploratory grant program, a competitive solicitation program administered through the University of California. This program supports the early development of promising, new scientific concepts that could impact the way we understand and/or address energy-related environmental issues. The program should enhance the current PIEREA research portfolio by funding focused projects in areas that are not presently being considered. Approximately $675,000 of PIER funds will be allocated to PIEREA exploratory grants. The maximum amount of any individual grant award is $75,000. The exploratory grant program is designed to tap into the broad research community to help ensure that PIEREA is open to research opportunities in the full range of energy-related environmental issues relevant to the mission of the PIEREA program.

ENERGY SYSTEMS INTEGRATION

2002 Progress Update

The Energy Systems Integration (ESI) program area conducts cross-cutting research critical to the improvement of California's electricity infrastructure. ESI takes a systems approach to identify and pursue initiatives. The ESI program mission is to develop an integrated infrastructure where electricity transactions are more effective, efficient, and reliable. The current research is focused in four areas: integrating distributed energy resources into the system; improving the efficiency and reliability of the transmission system; building an infrastructure for demand response to dynamic prices; and developing strategic, enabling technologies.

Distributed Energy Resources Integration (DERI) –

The DERI research program is implementing new cross-cutting research to address technology, process, and information gaps pertinent to the successful integration of distributed energy resources (DER) into California's electrical system. The program conducts system-level research in the areas of DER interconnection, grid effects, and market integration. The rapid and continuing changes in technology, markets, and consumer needs create unique and daunting challenges in making the research program relevant, focused, and effective in addressing these uncertainties. To deal with these uncertainties, the DERI program analyzed the value (and associated business models) that DER technologies can provide to the power system, consumers, and environment. This allowed the DERI program to select and prioritize research initiatives that will provide the greatest benefit and assist California in attaining the vision

of an integrated power system that includes DER. For more information on California's vision, see the *California Energy Commission Strategic Plan for Distributed Generation*, June 2002, P700-02-002. A combination of solicitations and sole-source contracts will be used to implement these research initiatives.

Enhancing Transmission System Capabilities

The ESI program's near-term effort is focused on activities that will produce a research plan to identify key issues and problems facing California in the area of transmission efficiency and reliability. A process that includes the opportunity for extensive public input will take a fresh look at what transmission research is underway or planned, and identify what high-priority research would be appropriate for ESI program activities. The research plan will be completed in May 2003 and will be implemented in summer 2003.

Energy Storage Technology for Grid Applications

The ESI program participated in EPRI's Energy Storage Working Group in Chicago, Illinois, October 16, 2002. The two projects funded in 2002 were *The Handbook for Current Energy Storage Options for Transmission and Distribution (T&D) Applications* and *Field Trials of Promising Prototype and/or Emerging Energy Storage Options for T&D Applications*.

The field trials project has released research data on its sodium sulfide battery project with A.E.P. Corporation. They have also initiated a field trial with the New York Transit Authority, who has installed ten 10 kW series connected flywheels, for a total of 1 MW of storage.

Demand Response to Electricity Prices and System Contingencies

Based on a series of scoping studies conducted in 2001, ESI has prepared and launched a demand response (DR) program. The vision of the research is to create a real-time, automated DR infrastructure that is simple to use and adaptively responsive to changing contingency and market conditions.

Four projects began in the fourth quarter of 2002. They will:

- Determine a baseline for automated DR in large commercial and industrial (LC&I) facilities in California.
- Develop DR-enabling technologies that decrease costs by a factor of 10 and increase functionality by a factor of 10.
- Study New York's real-time Pricing experience and determine how their results might help California.
- Develop and prioritize a DR research agenda for the CAISO and initiate high-priority tasks.

2002 RD&D Awards

Distributed Utility Integration Test (DUIT)

In May 2002, the Energy Commission awarded a $2,049,850 sole-source contract to Distributed Utility Associates of Livermore, California. The test site is located at the Pacific Gas & Electric testing facility in San Ramon, California. DUIT is the next step in assuring the safe, reliable, secure, and cost-effective inclusion of distributed energy resources into the electric utility grid. The goal is to advance the state of the art for DER integration by better understanding the benefits and challenges associated with substantial DER penetration into the electrical distribution system, and to gather and analyze data to characterize DER's actual value. Initial tests will address islanding and voltage regulation. This project is the first full-scale test of the effects of DER integration in the United States.

Develop a California Distributed Generation Interconnection Guidebook

In May 2002, the Energy Commission amended an existing sole-source contract with Reflective

Energies for $136,480 to create an Interconnection Guidebook. This book will help developers and utility customers understand the requirements and processes associated with DER interconnection in accordance with Rule 21.

The amendment also provides technical support for the contractor to participate in the National Interconnection Standards (IEEE P-1547) Workgroup. The contractor will take a lead role in developing the testing sections of the new standard, which has direct implications on the testing sections of California's interconnection Rule 21. Both efforts will help further streamline and standardize the DER interconnection process and thus reduce interconnection costs for DER systems, a key element in the future of California's electricity.

Methodology to Assess the Value of DER to the T&D Network

In June 2002, the Energy Commission awarded $616,689 to New Power Technologies to develop and demonstrate an analytical methodology that can identify where DER and demand response technologies can provide specific T&D network benefits to the looped primary distribution feeder. This will allow direct observation of the impacts of DER at the voltage levels at which they will be interconnected. A combination of power flow models will be used to identify network constraints and determine what combination of the DER portfolio projects will improve power quality and reliability. These benefits will be measured in both engineering and economic terms.

CERTS Microgrid Laboratory Testing

In September 2002, the Energy Commission awarded $1,090,000 in follow-on work to Lawrence Berkeley National Laboratory/Consortium for Electric Reliability Technology Solutions (CERTS) for continuing technology development of microgrids. The CERTS microgrid concept is an aggregation of generators, storage devices and loads, operating as a single system capable of providing both power and heat to customers. The majority of the microsources must be power-electronic-based to provide the required flexibility to ensure operation as a single aggregated system. This control flexibility allows the CERTS microgrid to present itself to the bulk power system as a single controlled unit that meets local needs for reliability and security.

The microgrid work builds upon the conceptual work conducted under the first contract and incorporates feedback on technology development gaps identified during a public workshop on microgrids held at the Energy Commission in May 2002. This new work will begin proving out the technical feasibility in a laboratory setting with hardware.

CERTS Demand Response Projects

In September 2002, the Energy Commission awarded $836,000 in follow-on work to LBNL for three demand response projects. The primary objective of the first project is to determine the current status of California's DR capabilities for typical large commercial, industrial, and institutional (LCI&I) facilities. The primary objectives of the second project are to (1) assess customer response to tariffs based on day-ahead wholesale market prices (i.e., real-time pricing or RTP) in a retail competition environment, and (2) assess the relative merits and relationship between alternative programs/strategies (e.g., real-time pricing tariffs and price-responsive load bidding programs administered by CAISO) that seek to increase customer participation in electricity markets. The primary objective of the third project is to work with CAISO to develop a research agenda to identify (1) how responsive loads could increase power system reliability and adequacy, (2) what behaviors are desirable, and (3) what reliability services (ancillary services) responsive loads could provide.

Utility Seismic Consortium

Non-seismically qualified substation equipment is a primary cause of damage and disruptions from earthquakes in California. Substation equipment needs to be seismically qualified using IEEE Standard 693. Through this award to the Electric Innovations Institute (E2I), a consortium of utilities, a methodology will be developed and then different critical items of equipment will be tested. Through consensus, the consortium will establish equipment support structure specifications. The consortium will submit recommended changes to IEEE Standard 693 to improve the reliability, quality, and safety of California's electricity.

CERTS Real-Time System Grid Management

In October 2002, the Energy Commission amended the existing Consortium for Electricity Reliability Technology Solutions (CERTS) contract with LBNL by $1,105,000 in the real time system monitoring and control area. The goal of this project is to lay the groundwork for a transition in reliability management philosophy from one based on passive readiness to one based on active participation and preemptive actions in response to impending emergencies. To accomplish this goal, three grid-reliability software prototypes developed during the initial CERTS contract—namely, the volt amps reactive (VAR) management adequacy tool, the generator frequency regulation and tracking tool, and a post-disturbance workstation will be deployed at the CAISO as a result of this contract. In addition, new graphic-geographic monitoring displays, prototype loop flow monitoring and management software, and validated stability nomograms will be developed and demonstrated at the CAISO. Ultimately, the completion of these tasks will contribute to the transformation of the electric grid to an automatic, switchable network.

High-Temperature Low-Sag Conductor

In February 2002 the Energy Commission awarded $100,000 to the E2I to evaluate the performance of selected high-temperature, low-sag conductors that are capable of significantly increasing the ampacity of thermally constrained transmission lines without the need for extensive tower redesign. Examples include 3M, CRAC, and Gapped conductors, and commercial forms of aluminum conductors steel-supported (ACSS) such as ACSS-TW.

The project will provide information on the operational performance of these new conductors through approximately three years of field trial experience and laboratory tests. In addition, the project will evaluate the performance of conductor fittings— including splices and dead ends—in both field and laboratory tests. Further, the project will compile practical engineering-type information to aid in designing, specifying, installing, inspecting, and maintaining the conductors. The results will serve to inform buyers and users of the technology.

Demand Response Enabling Technologies Project

In June 2002, the Energy Commission awarded a $3 million interagency contract to the University of California at Berkeley (UCB) through the California Institute for Energy Efficiency (CIEE). The initial objective of this project is to develop DR-enabling technology by leveraging ongoing RD&D funded by other agencies (e.g., the Department of Defense) at UCB in communication, information, and control technologies. The proposed effort will focus on specific energy-related tasks that can lead to dramatic decreases (hopefully by a factor of 10) in the installed cost of these technologies for DR applications. Initially, this project will attempt to develop DR-related micro-electromechanical systems (MEMS) sensors and actuators; open-system, mesh-architecture communication systems that can seamlessly share data; real-time, distributed-intelligence device networks that are self-organizing; and enterprise-wide, multilevel control strategies that can absorb legacy systems.

Success Stories

Volt Amps Reactive Management Tool Demonstrated at CAISO

Though our intergovernmental agreement with the LBNL, a new tool, the Consortium for Electric Reliability Technology Solutions–volt amps reactive (CERTS VAR) management adequacy tool, was recently demonstrated at the CAISO. This product provides system operators with immediate access to critical information on wide-area system voltages, and more important, to reactive reserve margins at critical grid locations through the use of sensitivity calculations and visual geographically oriented displays. Maintaining adequate voltages and reactive reserves, which vary according to local conditions, is essential for maintaining system reliability during and immediately after a significant disturbance on the grid. Prior to this tool, system operators received this information in the form of tabular displays or from single line diagrams that suppress the geographic relationship among voltages at various points within the system. Tools such as these could have been instrumental in alerting operators of dangerously low reactive reserve margins at critical stations and could possibly have prevented widespread outages on the West Coast in 1996. This project provides integrated research and technology development that will produce a quicker and more flexible response to increase the reliability of electricity services delivered to California's customers.

Intelligent Software Agents

This contract demonstrated the simulated use of intelligent software agents for control and scheduling of multiple distributed energy resources in a competitive energy market using 1999 pricing data. The software was developed into its final form and was made ready for field trial demonstration. The use of intelligent software agents reduces the level of expertise needed to own and operate distributed energy resources in California's competitive energy industry by having agents communicate over the Internet without direct human intervention. This project successfully tested the software in the laboratory and has generated interest by utilities and distributed energy resource stakeholders. The next step is to demonstrate and test the software in a field trial.

Streamlining Distributed Generation Interconnection Standards (FOCUS I)

Distributed energy resource systems are one of the paths toward greater energy independence in California. The FOCUS I project goal was to streamline the complicated process involved with interconnection, standardization, certification, environmental review regulations, and permits needed for installing of distributed energy resources. Initially, Rule 21 specified the interconnection, operating, and metering requirements for these generators, but Rule 21 proved to be too burdensome. The FOCUS I contract team worked to revise Rule 21 through a series of workshops and meetings. Technical issues were resolved for a range of applications. The Energy Commission presented its findings to the CPUC and they were adopted. Standardized interconnection has reduced interconnection costs by approximately 37 percent. "Simplified" interconnection applications cost only $800. Additionally, the utility review time has been expedited substantially. Finally, additional research and analysis has been initiated under a follow-on contract titled FOCUS II that will support the further refinement of Rule 21.

Real-time Transmission Line Ratings for Path 15

This follow-on PIER contract with the Valley Group demonstrated the feasibility of implementing real-time transmission line ratings for Path 15, one of the most congested lines in California. The cost in the fourth quarter of 2000 from congestion on Path 15 was $169 million. The Path 15 demonstration indicated greater than 390 MW of increased capacity to the line rating. Additional benefits can be realized

in the future at other highly congested transmission gates, including the positive benefits of avoiding future transmission projects.

Sagging Line Mitigator (SLiM)

In today's energy market, electric power transmission and distribution lines often get pushed to their limits while the power industry continues to face delays in installing new facilities. Thermal limitations arise when the maximum allowable conductor sag is attained. Historically this problem was addressed by expensive transmission and distribution line construction or reconductoring. However, Material Integrity Solutions has developed and demonstrated the Sagging Line Mitigator (SLiM) to solve this problem. As a result of PIER funding, SLiM achieved all of its project objectives and has proven that it can be manufactured and built to utility industry specifications. The relatively inexpensive, in-line device reacts to increasing conductor temperature by decreasing the effective length of the conductor in the span, mitigating the natural thermal expansion experienced by the conductor during high-temperature operation. This can represent a multi-fold increase of rated line capacity. The device is completely passive and requires practically no maintenance. SLiM is rugged and strong; simple to install, and designed to have a very long life. SLiM has attracted the interest of several utilities and EPRI, which with the consortium of interested utilities, has created a tailored collaboration to evaluate SLiM's performance on three operating transmission lines over the next 18 months.

Prototype of the SLiM Device Installed on a Transmission Line for Testing

Electric System Seismic Safety and Reliability

In California, it is never a matter of "if" an earthquake will happen—it is a matter of "when." In the event of a major earthquake, many first responders are critical in handling emergency situations. Police stations, emergency operators, hospitals, and fire departments are just a few of the people called in to help when the inevitable events occur. But before police, firefighters, doctors, and other emergency personnel can begin to do their jobs properly, there is one thing that each needs—electric power.

The Energy Commission and Pacific Gas and Electric Company (PG&E) are sponsoring research conducted by UC Berkeley's Pacific Earthquake Engineering Research Center (PEER). PEER has developed new tools and methods to make power transmission more reliable in the event of a major seismic event. One area of particular vulnerability in power systems across the nation are substations, which receive and distribute electricity. During past earthquakes, the major causes of blackouts were the catastrophic failures of circuit breakers, transformer bushings, and disconnect switches in substations.

Here are two ways researchers are currently working to make the system even more reliable.

Substation Porcelain Transformer Bushings. High-voltage wires leading into a substation's transformers are insulated by a porcelain bushing on top of the transformer. This material is very brittle, and researchers are testing new materials and anchorage designs for these bushings to help prevent their destruction during future earthquakes.

Although the bushings can be repaired, the loss of a 550 kV substation could affect electricity not only in California, but possibly disrupt service in surrounding states. In addition, repairing the

substation could involve a significant amount of time—at the very least several hours—during the crucial moments following a disaster.

Rigid & Flexible Conductor Studies. The PEER program and the Energy Commission are also researching the effects of seismic motion on other substation connectors. Rigid conductors typically used as connectors can snap during earthquakes. New flexible conductors, such as a new S switch, that bends but does not break during an earthquake, are being tested at this time. New flexible conductors and connectors will ensure a more reliable substation in an emergency.

Seven Distributed Generation Units Meet CA Grid Interconnection Standards

The successful certification of seven distributed generation units in accordance with Rule 21 (California's standard for interconnection of DG to the grid) lowers cost and streamlines installation by simplifying the interconnection approval process. Interconnection application cost is reduced by a minimum of 43 percent from $1,400 to $800 in many instances, due to the certification of certain equipment. Additionally, application review time by utilities is also reduced from 30 days to 10 days in many instances. This equates to an estimated $138,000 in interconnection application cost savings for Californians installing DG since 2001. This is expected to grow substantially as the DG market increases, with expected additional application cost saving of about $1 million for the next five years (Banc of America, 2000). The following equipment has been tested by a nationally recognized testing laboratory as having met the type and production testing requirements of California's Rule 21:

- Capstone 30 kW Microturbine Generator, Model 330
- Capstone 60 kW Microturbine Generator, Model 60
- Plug Power 5 kW Fuel Cell, Model SU1PCM-059622
- Tecogen 60 kW Induction Generator, Model CM 60H
- Tecogen 60 kW Induction Generator, Model CM 60L
- Tecogen 75 kW Induction Generator, Model CM 75H
- Tecogen 75 kW Induction Generator, Model CM 75L

CERTS Monitoring Applications Based on Synchronized Phasor Measurements

The CAISO is participating in the deployment of the next generation real-time system monitoring system and control applications. Current grid monitoring technologies take snapshots of the state of the system every *four seconds*, and operator's current monitoring tools are all based on these data. However, reliability threatening transient phenomena can occur over much shorter time scales (recall that the North American alternating current system operates at 60 cycles per second), making existing system control and data acquisition (SCADA) data unsuitable for monitoring system dynamics. Phasor measurement technologies record observations *many times per second* (i.e., they record the exact shape of the 60-cycle wave form). Deployment of this technology over wide areas is critically needed to support reliable region-wide and inter-regional transfers of electricity.

The original installations of phasor measurement technologies were supported by a joint DOE/BPA/WAPA/EPRI project in the mid-1990s. The cost of the demonstration was paid in full when information recorded by the devices became instrumental in determining the causes of the August 1996 West Coast blackouts. The data confirmed that the models used by operators to determine safe operating limits were in serious error. The phasor data are currently used by WECC to improve the validation and calibration of these models.

In the first phase of this project, CERTS integrated and delivered to the CAISO three post-disturbance assessment applications based on phasor measurements. CERTS staff originally installed the workstations in a room adjacent to the main grid operating theater, to be used as demonstration models. Within one month, because the workstations were working so well, CAISO operating staff, on their own initiative, moved them into the main grid operating theater. They are currently being used by CAISO operation support engineers to assist in calibrating the system models used to develop guidelines for real-time operations in coordination with WECC.

During the second phase of the project, phasor data currently collected by BPA, SCE, and PG&E are being transferred to a CAISO data concentrator via the WECC wide-area network to support new, prototype real-time monitoring displays that are being built by CERTS for CAISO dispatchers. The data linkage represents a significant institutional achievement within WECC and an important precedent for the type of data sharing that is increasingly needed to support the wide-area reliability management needs of the west.

As a result, the CAISO is pioneering the first-ever, real-time application of the phasor technology. The objective of the new workstations is to provide grid operators with phasor data in real-time so that they can obtain a more accurate picture of the actual health of the grid. The information will allow them to verify that they are operating within the boundaries of safe operation, as determined by the off-line planning studies, as well as whether the operating guidelines provided by these studies remain valid. Ultimately, real-time data provided by phasor and other real-time monitoring technologies will support creation of a future automatic, switchable grid that can sense and respond automatically to warning signs of grid emergencies. During the beta evaluation of the phasor system at the CAISO, operators utilized the wide-area monitoring system in real-time operations when both CAISO's primary and backup energy management systems suffered an outage. The CERTS phasor system provided the needed redundancy to allow CAISO operators to continue to monitor and manage the electric grid. Hence these CERTS tools have already demonstrated value in real-time operations.

Outlook

Distributed Energy Resources Integration (DERI)

Working in collaboration with consumers, DER equipment manufacturers, utilities, regulators, and DOE, DERI will initiate new research initiatives to address impacts to the electrical distribution system from DER and provide analytical information to assist in the development of market mechanisms to capture and monetize DER benefits. Additionally, DERI will develop a technology road map that integrates research activities with the potential technology commercialization and regulatory changes necessary to safely and cost-effectively integrate DER into California's power system.

Microgrids

The CERTs DER group will further the concept of the microgrid that is an aggregation of loads and distributed generation devices with a single interconnection to the distribution system. This concept seeks to control its presentations to the grid such that at worst it does no harm, and at best it offers additional reliability to the grid and customers, as well as economic benefits to customers. CERTS will design a laboratory test of the microgrid concept, beginning initial hardware modifications and conducting bench-level testing of control and protection systems. Additionally, potential future field demonstration partners will be identified and operational concerns identified in order to focus the laboratory test plan on real-world operational concerns.

Real-World Distributed Generation Interconnection Monitoring

The FOCUS II contract is implementing a real-world field-monitoring program of interconnected DER devices. The program includes a diverse mix of DER technologies interconnected to different distribution system designs of different California utilities. The goal of this case study is to collect power quality information about how DER impacts the distribution system in a real-world setting. This work complements laboratory system impact research being conducted under the DUIT project (contract #500-00-013). Results from this monitoring will be used to address concerns about protection, safety, and power quality raised by utility protection engineers and DER equipment manufacturers in the California interconnection rule development process. Data collection will begin in earnest in 2003 and interim analysis results will be provided.

Distributed Energy Resources Grid Effects

In collaboration with the DOE, the Energy Commission-funded Distributed Utility Integration Test (DUIT) facility will be commissioned in early 2003 and testing will begin on the highest priority interconnection issues—anti-islanding and voltage stability. The testing program will determine the positive and negative interactions of multiple DER devices with the electric utility grid. Like the FOCUS II, this project will address issues critical to removing barriers that prevent distributed energy resources from becoming a significant energy resource for California.

Analysis to Support Development of Market Mechanisms to Capture Distributed Energy Resource Benefits

DERI will initiate several research projects over the coming year that will analyze, develop tools, and demonstrate ways that distributed energy resources and demand response technologies can provide support to California's power delivery system, such as improvements in reliability, congestion, power quality, and security. These projects will focus on providing analytical data useful to policy and decision makers working to develop regulations and related market mechanisms that capture and monetize power system and environmental benefits that DER can provide California above and beyond those provided to the owner or operator of distributed energy devices (e.g., electricity or heat cost savings, uninterruptible power, etc.). These new projects will be coordinated with existing research within ESI, other areas of PIER, and the federal government, so that it is complementary and nonduplicative.

Enhancing Transmission System Capabilities

ESI has initiated a process to develop a comprehensive five-year transmission research plan. An in-depth study of current transmission research is expected to reveal where research gaps exist and what research activities could provide strategic public benefits. Through the use of scenario analysis, electric industry uncertainty will be evaluated and its potential effect on investment in transmission RD&D will be accounted for in the plan.

The four research focus areas that will be evaluated throughout this work are:

- Optimize the existing system
- Major capacity increases
- Advanced system operations
- Markets

Research and development needs will be reviewed in the context of the PIER public interest criteria and principles for supporting transmission research efforts. The draft research assessment and research priorities will be presented at a public workshop in March. The research priorities will be finalized in May and implemented in summer 2003.

Demand Response Demonstrations and Case Studies

This activity is in the process of choosing up to six large (>200 kW) commercial and industrial (LC&I) facilities that are capable of providing automated DR but have different ways of shedding load when given a price signal. Once chosen, these facilities will be sent a form of the dynamic tariff being developed by working groups made up of members of the Energy Commission, CPUC, CPA, and California's three main IOUs. The facilities will be monitored to determine the type and amount of DR that results from their automated "shed" strategies.

If all the facilities successfully shed load in response to the time-dependent price signals, then the state can set policy to "clone" these strategies and help other LC&I facilities implement the infrastructure necessary to support automated DR. If none of the facilities exhibit useful automated DR, then the results will be analyzed to determine the RD&D program that needs to be funded in order to achieve the desired response. Results between these extremes will indicate some combination of the proposed actions.

Demand Response Enabling Technology Development

A project at the UC Berkeley will begin early in 2003 to leverage existing research funded by the Department of Defense and private industry. Four technologies will form the basis of this medium- to long-term RD&D. The proposed work has the potential of reducing statewide DR implementation costs by a factor of 10 while at the same time increasing functionality, also by a factor of 10. The results of this RD&D will be new reference designs for sensors, meters, thermostats, network management tools, system integration designs, etc., that will make the DR infrastructure very cost effective and compatible with legacy systems.

DR Customer Response and Market Integration Studies

A study is underway to understand how the New York experience with real-time pricing (RTP) might relate to helping California solve its electricity crises. New York customers are being interviewed and several years of DR data are being evaluated.

Demand Response RD&D Agenda for the CAISO

A study to create an RD&D agenda for the CAISO is underway. An initial meeting in November 2002 with CAISO staff resulted in the development of objectives, scope, and issues. It is expected that a prioritized CAISO RD&D plan will be available in 2003 and that work on the highest priority recommendations will begin shortly thereafter.

ENERGY INNOVATIONS SMALL GRANT PROGRAM

2002 Progress Update

The EISG program assists the development of innovative concepts that are not already adequately funded through the competitive and regulated markets. A measure of the program's success is the degree to which the feasibility results attract follow-on funding for advanced development. Of the 98 active grant projects to date, 41 of the 47 completed projects have reported capturing $40.2 million in developmental follow-on funding (see Figure 2). Since the average time from start to finish for a research project is slightly over three years, and the PIER program began in 1998, follow-on funding did not begin until the year 2002. Approximately 25 percent of the follow-on funding has come directly from the PIER program, while 50 percent has come from the DOE. At a ratio of 11 to 1, the capture of follow-on developmental funding compares quite favorably with the $3.5 million originally awarded to the 47 projects for initial concept development.

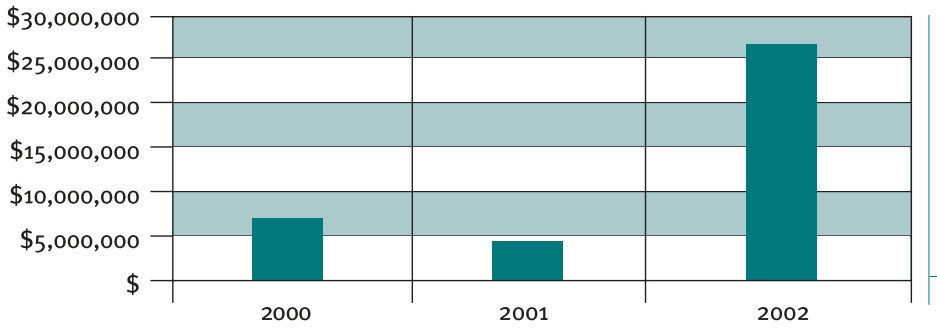


Figure 2
Capture of $40.2M Follow-On Funding for Further Development Resulting from $3.5M in completed EISG Grants (41 of 47 completed projects reporting)

During 2002, when three solicitation and award cycles were completed, the grant program processed a total of 207 proposals, compared with 232 total proposals processed in the year 2001.

2002 RD&D Awards

Agripower-Renewable Generation; Agricultural Waste and Forest-Thinnings-to-Energy

Harvey F. Brush of PMC Biomass, LLC., proposes to research the feasibility of a new biomass combustion turbine that uses an open Brayton Cycle and modular design.

Real-Time Energy Meter Radio Frequency Communications System

Elsmore William Bush, individual, proposes to research the feasibility of integrating narrowband VHF radio communications capability with selectable relay control into a DRM-2000 real-time electric meter that will collect, record, and transfer electric meter data to a central location.

Field Feasibility Determination of a Novel Energy-Saving Refrigeration Controller

Patrick D. French of ADA Technologies, Inc., proposes to research the feasibility of developing a frost sensor, microcontroller, and special algorithm to fine tune the defrost cycle for industrial/commercial refrigerators by activating and terminating defrost cycles only when frost appears on the evaporation coil.

Development of an Effective Fire-Shield for Power Poles by Custom Tailoring a Mineral Polymer Material

Clem Hiel of Composite Support & Solutions, Inc. proposes to research the feasibility of developing a low-cost fire shield for power poles made out of a newly developed mineral polymer material and glass fibers.

Microturbine-Based Building Energy System

Nissen A. Jaffe, individual, proposes to research the feasibility of using a variable, partial recuperator exhaust bypass on a natural gas–fired microturbine that can be used for absorption cooling, space heating, and power generation in commercial buildings. A feature that distinguishes microturbines from conventional small gas turbines is the recuperator, a heat exchanger used to preheat combustion air with exhaust products.

Ultra-Reduced Emissions Burner for Gas Turbine Combined Cycle (GTCC) and Combined Heat and Power (CHP) Applications

John T. Kelly of Altex Technologies Corporation proposes to research the feasibility of a duct burner design for gas turbine, combined-cycle systems that

can divide the flame into several zones, thereby allowing better control of flame stability, CO emissions, and NOx emissions.

Flexible Low-Emissions Combustor (FLEC) for Renewable Fuels

John T. Kelly of Altex Technologies Corporation proposes to research the feasibility of developing a flexible low emissions biomass combustor for renewable fuels that are poorly formed, inconsistently sized and contain high moisture. FLEC uses special features to handle inconsistently sized and high moisture wastes.

Spectrally Enhanced Ceramic Incandescent Emitter

Devon R. McIntosh of Sonsight Inc. proposes to research the feasibility of a new type of composite ceramic oxide emitter for an incandescent light bulb that is 300 percent more energy efficient than conventional incandescent bulbs, produces light that is closer to the natural sunlight spectrum, and has an expected color rendering that is superior to other general lighting sources.

High-Volume Manufacturing for Low-Cost, Flexible Solar Cells

Shalini Menezes of InterPhases Research proposes to research the feasibility of developing a new flexible thin-film solar cell based on negatively doped copper indium diselenide (CIS) with fewer cell components relative to the state of the art, positively doped CIS cell.

IEM's Low-Cost Building Performance Infrared Camera

Zack Mian of International Electronic Machines Corp. proposes to research the feasibility of incorporating cost-cutting innovations in the design of an infrared camera that will reduce the retail cost from $12,000 to less than $2,500, thereby expanding its use in energy audits of commercial and residential structures.

Quantitative Building Cooling of Tile Roofs Coated with Solar Infrared (IR) Reflective Coatings

Joseph C. Reilly of American Rooftile Coatings proposes to research the feasibility of new IR reflective coatings that can be applied to residential concrete or clay tile roofs to achieve a minimum 40 percent solar reflectance.

Improvement of Rechargeable Lithium-Ion Batteries Performance by Surface Modification of the Cathode

Pieter Stroeve of University of California, Davis, proposes to research the feasibility of using lithium manganese oxide as a cathode material in rechargeable lithium-ion batteries to achieve higher voltage, lower cost, and increased safety.

Desiccant-Enhanced Indirect/Direct Evaporative Cooling System

William A. Belding of Innovative Research Enterprises proposes to research the feasibility of a new air conditioning design that incorporates indirect/ direct evaporative cooling and dehumidification with gas regeneration. The proposed system employs desiccant components within the indirect cooling stage, thus simultaneously dehumidifying and cooling the process air.

Energy-Efficient Process for Using Membrane Technology to Treat and Recycle Agricultural Drainage Water

Ronald J. Enzweiler of Water Tech Partners proposes to research the feasibility of using a more energy efficient two-stage membrane process for desalinating and recycling agricultural drainage water.

Solid State Electrolyte for Dye-Sensitized Solar Cells (DSSCs)

Russell Guadiana of Konarka Technologies, Inc. proposes to research the feasibility of using a

specially formulated gel as an electrolyte in dye-sensitized solar cells (DSSCs) that permits effective encapsulation in the manufacturing process. The project includes development of a solid-state electrolyte that outperforms the liquid electrolytes presently used for DSSCs.

Prototype and Demonstration of Vision-Tuned fluorescent Lamps

Kevin W. Houser of University of Nebraska-Lincoln. proposes to research the feasibility of developing more energy-efficient fluorescent lamps in which a greater percentage of the radiant energy is used to produce light that is optimized for human vision. A significant opportunity exists to optimize light source spectra, which will lead to better vision with a minimum expenditure of energy.

Low-Cost, High-Efficiency, Solar Cell Fabrication Using Inkjet Printing

Neil Kaminar of Sun Power Corporation proposes to research the feasibility of using low-cost, high-resolution inkjet printing technology to fabricate high-efficiency solar cells. The standard commercial inkjet has a resolution that is twice as good as the 100 µm resolution available from the more expensive photolithographic processing currently in use.

Development of Single Fan Multi-Stack Exhaust Systems

Mingsheng Liu of University of Nebraska proposes to research the feasibility of a single fan multi-stack laboratory exhaust system expected to reduce the annual fan energy by 50 percent in research and high-technology facilities.

Automating Window Sunshade Control: Toward the Zero-Energy House

Murray Milne of University of California, Los Angeles proposes to research the feasibility of developing a new kind of intelligent window thermostat that uses indoor/outdoor temperature sensors and a sunshade controller to reduce the heat load on air conditioners in the summer.

Test Program for High-Efficiency Turbine Diffuser

Thomas R. Norris of Consultants in Engineering Acoustics proposes to research the feasibility of reducing backpressure on turbines designed with a right-angle bend in the outlet by inserting aerodynamic vanes and devices inside the exhaust diffuser.

Sealing and Contacting to Novel Integrated Solid Oxide Fuel Cells

Scott A. Barnett of Northwestern University proposes to demonstrate a novel sealing and electrical contacting method for solid-oxide fuel cells (SOFCs)

Low-Cost, Energy-Saving Motor Controller for Residential and Industrial Buildings

Patrick Chapman of University of Illinois at Urbana-Champaign proposes to research the feasibility of integrating a unique motor drive with a specially designed three-phase motor that can be driven with single-phase power and will varying speed to follow the load.

Detecting Optimal Fan Pressure

Clifford Federspiel of Federspiel Controls proposes to research the feasibility of using a new algorithm for more accurately determining the optimal pressure at which to operate variable air volume (VAV) air-handling systems. Improved VAV operation will increase the energy efficiency of the overall climate control system.

Fault Location Techniques for Distribution Feeders Containing Distributed Generation

Adly Girgis of Clemson University proposes to research the feasibility of a computational strategy for determining the fault location in a transmission

network containing distributed generation resources. The strategy will be based on an analysis of the voltage and current waveforms on the three phase lines at various points in the distribution network.

Steady State Security Assessment of Deregulated Power Systems

Elham B. Makram of Clemson University proposes a method to evaluate the state of the transmission network following possible system contingencies. A quantitative assessment of the extent to which each bilateral transaction adversely affects the transmission network will be demonstrated.

High-Efficiency Organic Thin Film Solar Cell

Shalini Menezes InterPhases Research proposes to research the feasibility of a low-cost organic thin-film solar cell device that can be fabricated using a simple robust process for organic/polymeric materials.

Unified Power Quality Conditioner Using One-Cycle Control

Keyue Smedley of University of California, Irvine proposes to demonstrate the feasibility of using a one-cycle control circuit design to simplify and reduce the cost of a unified power quality conditioner that can compensate for reactive power flow, harmonic distortion, and voltage variation/sag.

Success Stories

Innovative Gearbox Design for Large Megawatt Range Wind Turbines

Dehlsen Associates, LLC received a $75,000 EISG award on February 1, 2001, to research the feasibility of a novel gearbox design for use in large megawatt range wind turbines.

As turbine rotors grew in diameter, and their revolutions per minute decreased to keep tip speeds down, the resulting high-torque inputs increased the cost and reduced the reliability of traditional gearboxes. Dehlsen Associates successfully demonstrated a subscale gearbox and controller design consisting of an input shaft-driven bull gear that drives a number of pinions around its periphery. These pinions, which drive several small generators, divide the input torque load at its highest point and reduce gear tooth stress.

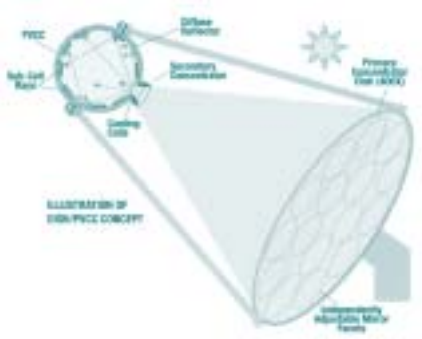
Since the start of this EISG grant project, Dehlsen Associates has obtained a total of $14.3 million in follow-on funding, including $237,000 from the U.S. Department of Energy WindPACT program in 2001, $1.3 million from the PIER program through SMUD in 2002, and $12.8 million from the DOE Low Wind-Speed Turbine program in 2002.

Dehlsen Associates Subscale Gearbox and Controller Design

Photovoltaic Cavity Converter Exceeds Expectations

On February 1, 2001, United Innovations, Inc. received a $74,992 EISG award to research the feasibility of focusing the 50-sun output of a non-tracking "insect eye" concentrator into a novel hyper-spectral photovoltaic cavity converter to achieve a conversion efficiency of at least 38 percent. The primary innovation is in the cavity converter, which utilizes a combination of low-cost, single-junction cells coated with special Rugate filters that pass only the spectrum needed by the cell and reflect the remaining spectrum to other cells in the cavity capable of utilizing the remaining solar energy.

While the insect eye concentrator did not perform to expectations, the cavity converter was confirmed capable of achieving 43 percent conversion efficiency at 50 suns, exceeding expectations by 5 percent. Efforts are now underway to test the cavity converter with a tracking dish concentrator capable of generating up to 500 suns.



United Innovations Photovoltaic Cavity Converter

United Innovations has received a total of $687,000 in follow-on funding from two sources, which including $498,000 from DOE/NREL (PV Technologies Beyond the Horizon) and $189,000 from DOE/NREL (Concentrating PV Module Design for Near-Term Demonstration and Test).

Concept-to-Market Success in Roofing Tile Technology

In 1999, PowerLight, Inc., received $74,885 in EISG funding to develop a photovoltaic roofing tile technology. The innovation increases the value of PV power in two critical ways: (1) through the cost savings associated with the roofing function, and (2) by including a "cool roof" feature that reduces normal heat load on the roof, thus saving the building's electrical load.

Based on the successful proof of feasibility, PowerLight obtained follow-on funding of $1.5 million from PG&E that led to commercialization of the technology. The company has since become well established and successful at marketing its products.

Outlook

An independent review of the EISG program will be completed in the spring of 2003 by a team of experts in energy research. The team has provided preliminary findings that the program is well managed and executed, is meeting an important need of behalf of PIER and California, and is highly successful in attracting follow-on developmental funding. The review is expected to suggest measures to further enhance the value of the program to California public interest energy research. Since the Energy Commission approved extending the EISG for two years beginning September 2002, the extension provides the opportunity to make program adjustments. One of these, improving the feasibility analysis reports (FARs), is already underway based on language in the program extension.

The purpose of the FARs is to provide grant awardees, PIER staff, and the public with an independent, expert assessment of project results. Stronger FARs will be valuable to those grantees whose research has been successful, because they can be key in moving grant results into the development phase of research and subsequent steps to commercialization.

C. PIER PROGRAM ADMINISTRATION

Administrative Streamlining and Standardization

Administrative streamlining is an effort within PIER to increase the efficiency and effectiveness of administrative tasks by eliminating unnecessary or duplicated tasks; reducing bureaucracy; and reducing the number of ineffective, time-intensive processes.

On March 29, 2000, staff submitted to the RD&D committee a detailed analysis of streamlining

activities and opportunities. In June 2000, implementation activities were expanded to include direct coordination with the IRP members assigned to the Administrative Streamlining team. The coordinated Energy Commission/IRP team met twice and identified the following issues:

- Reduce to four months or less the total amount of time from the start of the contract initiation process to the date of a fully executed contract.
- Develop agreements that have the flexibility needed for research projects, yet still have appropriate levels of accountability.
- Improve the consistency and quality of contract management.

Since then, the Administrative Streamlining team has developed a team and a process affectionately known as SPARKEY. Built within a Microsoft Excel spreadsheet, SPARKEY helps PIER staff by providing automated, standardized templates of the Energy Commission-required forms for initiating and preparing contracts. During the contract initiation phase, SPARKEY assists in the communication and liaison work needed between the Energy Commission contract manager (CCM), the Legal Office, the Budgets Office, the Contracts Office, and the contractor. SPARKEY's templates can be distributed to and completed by the CCM, the contractor, and SPARKEY.

SPARKEY also assists PIER staff in working through the multitude of steps needed to transform a proposed award into a contract, including project work statements and special terms and conditions. SPARKEY additionally has the ability to track where, when, and to whom each relevant document has been sent. More than three-quarters of PIER staff currently use this system as their contract initiation and preparation tool.

As the result of SPARKEY, contract initiation times decreased and stabilized. The first contracts coming out of SPARKEY averaged 216 days (7.21 months) from start date to full execution, and SPARKEY clients could be 95 percent sure that their contracts would be executed in as little as 4.95 months or as much as 9.46 months.

In 2001, efforts were made within the SPARKEY team to standardize templates that would assist in streamlining the PIER contract initiation process by making the information collected on each contract more consistent. In addition to the templates, a dedicated team of administrators was put in place in early September 2001. The results of this interdepartmental team have been remarkable:

- Average length of time from start date to fully executed contract has decreased to 102 days (3.40 months), representing a decrease of 53 percent.
- SPARKEY clients can be 95 percent sure that their contracts are executed in as little as 3.01 months or as much as 3.79 months.
- The IRP goal of executing a contract in four months or less has been met.

Because the processes used during the amendment phase of a contract are similar to those used in initiating new contracts, PIER personnel also utilize SPARKEY during the amendment phase. During amendment, SPARKEY relies on many of the same templates used during initiation.

SPARKEY is also working on further standardization of various contract templates, such as that for the statement of work. This work is of note in the review being done by the PIER Business Process Project team, as it has a direct effect on the contracts process itself.

PIER Oversight

In response to the Independent Review Panel Final Report comments, PIER convened technical review committees for each of the six technical program areas. These committees met between September and December 2002. Each committee met to review specific program area issues, portfolios,

collaborations, and future plans. Each committee submitted recommendations to assist in future PIER and program area planning.

Results/Summaries of Each Program Area Technical Review

The PIER program manager convened separate committees of technical experts to review the six PIER program areas. Each technical review committee was charged with evaluating the program area portfolio and future plans for program improvement based on presentations by program area leads. Universally, the committees expressed praise for the quality of staff within each program area, further commenting on their dedication, enthusiasm, and accomplishments to date. In general, the committees agreed that program areas were addressing important issues and seeking to collaborate with key institutions. They encouraged identification of clear goals and metrics for each program area and suggested that the integration of program areas and their links with both public policy and the marketplace should be more clearly mapped.

Each committee met with program area staff and contractors to discuss program area history, rationale, issues, strategy, and stakeholders. Each committee prepared a written evaluation, addressing questions posed by the program area lead.

On October 17 and 18, 2002, a committee of experts conducted a technical review of the **Environmentally-Preferred Advanced Generation** program area. The committee supported the program area assumption that clean, environmentally preferred, distributed generation will be important in California's future energy mix. The committee suggested that a market or applications study should be undertaken to link program goals with technology development. They further suggested initiating a study to determine the program-related impacts of a possible future transition to a "hydrogen economy." The committee encouraged the continued use of critical project reviews to manage funded projects, since they reduce the risks associated with RD&D projects. They cited outstanding coordination with external research organizations and the high level of PIER funds leveraged. To keep up with RD&D developments and to create and leverage new opportunities, the committee encouraged continuation of peer contacts, site visits, and partnering. The committee further encouraged coordination with appropriate public agencies and programs regarding issues of rate structure, institutional policies, and grid interface for its effect on technology development needs.

A technical review committee met on October 21 and 22, 2002, to review the **Residential and Commercial Buildings Efficiency** program area. The committee supported the program area as an efficient way to address a clear need. The committee was favorably impressed with the quality and scope of the projects, the portfolio balance, staff quality, and steps taken to manage research so that the results can quickly become commercial products that benefit California ratepayers. The committee highlighted a number of issues in which the program area should continue to improve. These issues include addressing buildings as integrated systems with complete life-cycle costs; using better estimates of growth demand and its contribution to peak electric demand; setting portfolio priorities; using a map of institutional relationships and roles to increase communication and guide coalition building; funding partnerships with established institutions, focusing on systems engineering efforts to reduce new residential construction and operating costs; reducing management detail to address high workload; balancing management of intellectual property to ensure research results in commercialized products; and maintaining links with end users.

The technical review of the **Renewable Energy Technologies** program area was conducted on October 24 and 25, 2002. The committee was impressed with the able and enthusiastic staff as well as the existing program components. The committee was also supportive of the quality of the funded projects and the links with federal RD&D functions. The committee suggested that the links and interaction with other Energy Commission and California renewable energy efforts should be clarified. The committee encouraged future articulation of the public interest aspects of program components and articulation of policy adjustments in response to changing energy markets and policies.

The **Energy-Related Environmental Research** program area technical review committee met on October 31 and November 1, 2002. The committee praised the range of activities, external communications established, and the potential for significant contributions toward California's future energy security. The current program area focus on land use and habitat, aquatic resource issues, cross-cutting efforts to improve indoor air quality, and climate change research efforts were highlighted by the committee. A number of specific issues were suggested for future program area attention, including minimizing the impacts of transmission infrastructure replacement on land use and habitat; minimizing the effects of future water supply changes and hydroelectric use changes on land use and habitat; improving air quality through energy efficiency and load management; and mitigating carbon sequestration. Suggestions to improve program area effectiveness include linking research results to the policy process, increasing emphasis on future needs and cross-cutting research, and increasing collaboration to maximize resources.

The **Energy Systems Integration** program area technical review committee met November 21 and 22, 2002, for the program area review. The committee found the ESI program area to be a professional effort by dedicated staff, successfully meeting the legislative mandate. The committee suggested that program area staff need to have more freedom and exposure to ideas and other programs to allow their development and to carry out a plan responsive to a quickly evolving industry structure and technologies. Likewise, the committee suggested the program area plan should be flexible. The committee recommended increasing ESI's scope to address energy markets rather than limiting the scope to electricity markets because of interdependence of energy sources within the market. The committee suggested identification of metrics for project selection and success for each focus area and further clarification of how the ESI activities relate together and with other PIER program areas. Further, the committee suggested that more emphasis should be placed on evaluation of the contractor management team to ensure the team has a viable business plan; the ability to execute the plan will increase project successes.

The committee provided specific comments regarding ESI focus areas. The committee suggested that a certification program for DER equipment and systems should be established as a prominent program activity. Placing more emphasis on short-term results and reduction of project duration was suggested for activities while the market structure is quickly evolving. The committee also suggested that transmission issues receive priority attention and that an opportunistic-based vision and plan are needed for the transmission focus. The committee recommended employing the strategic systems focus area as a starting point to address new issues before they are assigned to another focus or program area. However, the committee cautioned that resources will be needed to study these issues.

The **Industrial/Agricultural/Water End-Use Energy Efficiency** program area technical review committee met on December 5 and 6, 2002, for the program area review. At this time, no report has been received from the committee.

Technology Transfer

The value of energy RD&D is lost if the results are not made available to potential users, investors, or marketers. Concurrently, many smaller businesses do not have the resources or expertise to launch their own clean energy technology or products. The PIER program addresses these technology transfer issues through a variety of innovative means.

In October 2002 the Energy Commission, along with the National Renewable Energy Laboratory (NREL) and the New York State Energy Research and Development Authority (NYSERDA), cosponsored the 15th Industry Growth Forum in Albany, New York. The forum focused on bringing together California-based clean energy companies with potential investors and offered some PIER-funded projects the chance to present their business plans to venture capitalists and angel investors. In addition, the PIER program initiated its business incubator pilot program, which assists PIER-funded projects to develop a business plan or marketing strategy that will help them grow a promising business. Applications for incubator assistance were evaluated in early 2002, and eight successful candidates are receiving business consulting assistance through the Environmental Business Cluster (EBC), an affiliate of the National Alliance of Clean Energy Business Incubators.

Technology transfer efforts in 2002 also included the production of three more in an ongoing series of one-page project success stories, bringing to nine the number of completed success stories. Those success stories are highlighted on the dynamic PIER website, which contains all published final reports on research contracts, a program-area information focus, and information about funding opportunities. Four more success stories are under development and will be completed in early 2003.

In addition, PIER cosponsored technical conferences with other distinguished organizations to leverage PIER funds for the more efficient transfer of information and technical knowledge.

PIER Program Reporting to the Legislature

In accordance with PRC Section 25620.5(h), the Energy Commission is required to file semiannual reports with the Legislature for the PIER program (on or before June 1 and December 1 of each year as requested by the Office of the Legislative Analyst). These semiannual reports provide the required "evaluation of the progress and a status of the PIER program's implementation" for each six-month period, and also provide input for the Energy Commission's more detailed PIER annual report required pursuant to PRC Section 25620.8. In 2002, the Energy Commission completed and filed all of these reports within their legislative deadlines.

2002 Financial Statement (January through December 2002)

The financial statement for the 2002 PIER program is shown below.

2002 Income	
Payments from Utilities	$62,500,000.00
Interest Earnings	$5,703,965.84
TOTAL EARNINGS	$68,203,965.84

2002 Expenditures	
PIER Encumbrances	$74,529,819.00
PIER Administration	$1,738,401.00
TOTAL EXPENDITURES	$76,268,220.00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FUTURE Program Directions

A. FUTURE FUNDING EFFORTS

PIER planning for 2003 provided for the development and encumbrance of funding activities primarily focused on the demand side: increasing end-use energy efficiency and improving demand response technologies. PIER will continue this emphasis in 2003–04, while also being responsive to new legislation. In particular, PIER will be developing, demonstrating, and assisting in the deployment of new renewable energy technologies as a result of the passage of SB 1078, the Renewable Portfolio Standard (RPS). The newest enabling legislation for PIER, SB 1038, also allows PIER to encumber funding for market transformation, which will be critical for meeting RPS goals.

PIER will also develop new initiatives in transmission systems RD&D (hardware and software) as a result of language contained in SB 1038. PIER will also focus its fossil fuel–fired distributed generation activities on addressing new California Air Resources Board (CARB) regulations developed under SB 1298. PIER will work closely with CARB staff in this endeavor.

Over the next 18 months PIER plans to develop, enhance, or extend programmatic activities in buildings commissioning and energy efficiency, air cooling technology, and lighting efficiency. PIER is also working to develop and deploy new energy-efficient technologies into the food and agricultural industrial sectors.

The Energy Commission will commence a new energy storage technology program that will deploy applications in the areas of industrial power quality and reliability, transmission congestion reduction, and renewables. The Energy Commission will also address the development, demonstration and deployment of energy-efficient technologies for water use, treatment and reuse, and transportation. This effort is consistent with growing concerns about this critical California resource.

The Energy Commission will continue the development and demonstration of distributed energy resource integration technologies, as well as continuing work in demand response RD&D. This will include continued funding of activities at LBNL for the development and deployment of CAISO system management tools.

PIER research and assessment activities will continue in the environmental area. There will be a new focus on land-use impacts of transmission systems and biomass impacts and opportunities. Air quality work will continue to be closely linked to new regulations developed by CARB. PIER will also develop a regional climate change center to address potential impacts of global warming and to inform policy development on a state level.

Finally, as a result of a new SB 1038 requirement to fund market transformation activities, PIER will work more closely with the CPUC/Utility Technology Coordinating Council and assess mechanisms for incorporating successful technologies into the Energy Commission's Renewable Energy Technologies program activities. These are consistent with the need to better integrate public goods charge programs to benefit the California ratepayers.

B. COORDINATED FUNDING EFFORTS

In 2003, the Energy Commission will continue to build upon successful collaborations with the DOE and other funding institutions. These are all the more critical at this time, since collaborative efforts lead to more productive use of RD&D funds while enhancing the flow of funds into California.

The Energy Commission continues to work successfully in a number of areas with DOE's Office of Energy Efficiency and Renewable Energy (DOE/EE), and is entering the third year of collaboratively funding the Consortium for Electric Reliability Technology Solutions (CERTS), based at Lawrence Berkeley National Laboratory. Incorporating new management software tools into the CAISO has produced early successes, and CERTS continues to work with the CAISO to develop additional software tools for more efficient and reliable system operation.

The Energy Commission is collaboratively funding technology development of advanced reciprocating internal combustion engines (ARICE) with DOE/EE. This collaboration has led DOE to modify its program objectives to be more in line with meeting California's environmental requirements, particularly CARB emission standards, which become effective in 2007.

Building upon earlier successes with DOE/EE and the NREL in small-scale biomass technology development, a new focus will be wind energy technologies designed to be economic in California's suboptimal wind region. This is a successful collaboration for the state, since much current national RD&D has been directed toward wind turbines designed for the high plains.

The Energy Commission will also maintain collaborative technology development activities in buildings and appliances end-use energy efficiency. Work in building commissioning and air cooling continues. In addition, the Energy Commission is providing leadership in a new lighting technology initiative.

The Energy Commission is effectively collaborating with DOE/EE and NREL in developing technology for distributed energy resource integration. The Distributed Utility Integrated Technology (DUIT) program was started by the Energy Commission and is now also being funded by DOE. In a separate collaboration with DOE/EE, work is underway to develop a new initiative in communications, control, and information technology development to be focused on demand response. Part of this program will also include continued funding of UC Berkeley's Center for Information Technology Research in the Interest of Society (CITRIS). A distributed energy resources initiative also includes working closely with the Electricity Innovations Institute (E2I), an EPRI affiliate by providing leadership in getting this important public-private partnership activity started.

The Energy Commission is also working with DOE/EE in implementing an energy storage technology development, demonstration, and deployment program. DOE has funded Sandia National Laboratory to support the Energy Commission and will cofund this activity. This energy storage effort will be broadly based on improving industrial power quality and reliability, reducing transmission congestion, and providing storage for intermittent renewables.

The Energy Commission is also working with DOE/Fossil Energy (DOE/FE) on several initiatives: collaborating on programs reducing fossil-fuel turbine NOx emissions; developing a new technology program based on use of ramjet technologies; and planning to cofund the development of a regional geological carbon sequestration center working both with industry and the Western Governors Association. Working with DOE/FE as part of the California

Stationary Fuel Cell Collaborative (CSFCC), led by CARB, in the coming year, the Energy Commission plans to cofund fuel cell demonstrations with the U.S. Department of Defense and the South Coast Air Quality Management District as part of CSFCC activities.

The Energy Commission is also working with the U.S. Department of Commerce/National Oceanographic and Atmospheric Administration (NOAA) to develop a regional climate change center, with activities focused at Scripps Institute in San Diego. This work will support longer term electricity system planning and analysis in California.

The Energy Commission is currently leading a collaboratively funded activity with DOE/EE and the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). This work focuses on developing accepted testing criteria and standards for distributed generation technologies. Based on the active participation of the Energy Commission, a new coordinated funding effort at the national level is developing through ASERTTI.

ASERTTI is an organization of growing state and regional energy research and deployment institutions with support from states such as New York, California, North Carolina, South Carolina, Massachusetts, Florida, Wisconsin, Illinois, Connecticut, and Washington. The new ASERTTI program is called the State Technologies Advancement Collaborative (STAC) and it is being designed to jointly plan, fund, and conduct a federal/multistate research and deployment agenda consistent with the strategies of both the federal government and the states. An Energy Commission manager serves on the STAC executive board. ASERTTI is working with the National Association of State Energy Officials (NASEO) and the DOE to receive an initial $2 million in 2002 with more funding to be allocated by Congress in 2003.
The current collaborative funding that substantively supports the Energy Commission/PIER initiatives is approximately $159 million (see Figure 3). These collaborations provide both increased funding to California-based organizations and additional potential benefits to California ratepayers.

Collaborative funding should not be confused with match funding, which increases the value of PIER's research contracts significantly. Through 2002, PIER has provided nearly $232 million for research contracts, while project proponents have cofunded the R&D with nearly $333 million in matching funds.

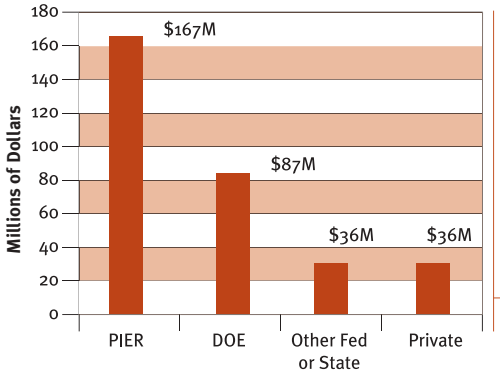

Figure 3
Effective Collaborations Significantly Extend the Reach of California-Focused Energy RD&D


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ATTACHMENT 1 Acknowledgments

The Energy Commission wishes to acknowledge the invaluable contributions made to the PIER program by the Energy Commission's staff, the members of the PIER Policy Advisory Council, and the many concerned citizens who have actively participated in PIER-related advisory groups, planning focus groups, and other program forums to date. This participation has provided essential input throughout the program's development, and the Energy Commission will continue to seek such input and assistance in the future as it strives to further develop and improve the PIER program. Finally, the Energy Commission wishes to acknowledge the many highly talented and creative researchers and research organizations participating in the PIER program. Without the team effort of these various dedicated participants, the important public benefits of the PIER program could not be achieved.

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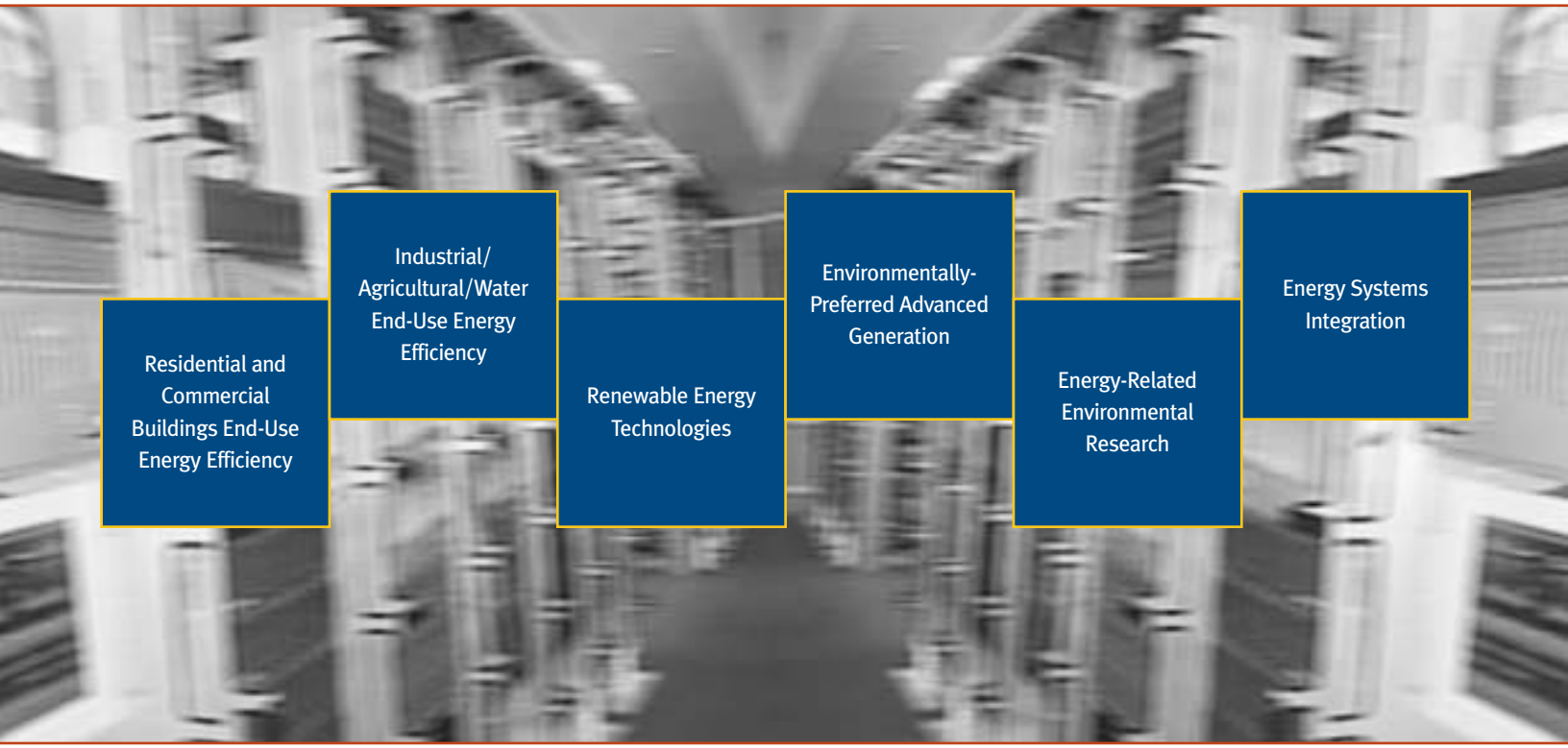

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